ROCKET MASS HEATERS

THIRD EDITION

IANTO EVANS AND LESLIE JACKSON

A COB COTTAGE CO. PUBLICATION

ROCKET MASS HEATERS

Superefficient Woodstoves YOU Can Build

THIRD EDITION

Ianto Evans
Leslie Jackson

A Cob Cottage Company Publication
2006 — 2014

Purchased by Johnathan Yelenick, johnathan.yelenick@gmail.com #11023292

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Thanks

We involved certainly dozens—perhaps hundreds—of people in making this book. Originally, its purpose was to get people trying things. That worked far better than we could have anticipated. The brush fire we started almost accidentally 10 years ago has spread rapidly so now it's out of control, roaring away through North America and Europe with a smaller but intense outlier burning in Japan.

We need to thank you all for the things you tried, the people you told, and above all, for being communicative, telling us what you're doing. A handful of people really stand out but it was hard to decide whom to thank first. So we'll go in order of height.

LINDA SMILEY, who after her success with *The Hand-Sculpted House* has been an almost invisible support to the whole project. She has suffered dozens of overenthusiastic filthy pyros in her house, constant experiments and rebuilds, smoke, firewood shortage, and singed clothes. Thank you Linda.

ART LUDWIG, our Secret Weapon in the high-end billionaire zone, who has used his creativity and analytic expertise to offer new thoughts about how Rocket Mass Heaters (RMHs) may fit into the twenty-second century. Thank you Art.

DENNIS KUKLOK, illustrator, writer, cartoonist, who with great clarity of mind always asks the most difficult questions. Thank you Dennis.

MICHAEL G. SMITH, for unwavering patience and follow-through, 15 years editing *The Cob Web*, and being a great friend. Without Michael, there would be no Cob Cottage Company. Therefore no publishing, no network, possibly no *Rocket Mass Heaters*. Thank you Michael.

SHANNON DEALY, who set up a website for Cob Cottage Company before anyone had ever heard of such a thing in the early 90s and has mothered it ever since.

FLEMMING ABRAHAMSSON in Denmark, who snatched the baton and promoted Rocket Stoves in Europe. Thank you Flemming.

LARRY WINIARSKI, who 30 years ago helped Ianto better understand the physics of fire. Thank you Larry.

KIKO DENZER, for the Introduction, wonderful storytelling about his stoves, persisting when the air was smoky and the forecast chilly (in his house, that is), for constant advice and support. Thank you Kiko.

MAX AND EVA EDLESON. Max grew up in Indonesia and built for years in Argentina, so he knows fire very well. Now he and Eva build mass heaters, teach pyrotechnology, and run "Fire-speaking." Thank you Max and Eva.

TAMMY VAN, who has been Cob Cottage's office manager since 2010, stoking her RMH daily. She manages the Bandon, Oregon, demonstration site for RMHs and cob, offering workshops there. Thank you Tammy.

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LARRY JACOBS, who owns Jacobs Farms and is central to Del Cabo Organic Co-op. With partner SANDRA BELIN Larry ran the Lorena Stoves project in Guatemala after Ianto ran off to California. In Oregon Larry was in on the earliest ancestors of RMHs, 35 years ago. Thank you Larry and Sandra.

PETER VAN DEN BERG, punctilious researcher in The Netherlands, constantly in dialogue with RMH developers worldwide. He's been tinkering in his lab to combine the best of Rocket Stove tech with the scalability and precision of masonry stoves. Peter is very active in the online RMH discussions, bringing practicality, experience, and science as well as lots of creative, original, testable ideas. Thank you Peter.

LASSE HOLMES, who read this book, showed up on the forum with his good ideas and is now in here in significant ways. He's also the best brewer in Alaska and was a gracious host to Leslie last winter. Thank you Lasse.

BERNHARD MASTERSON, who lives with an RMH in his self-built cob house and is a professional teacher instructing on cob, Natural Building, and ceramics. Thank you Bernhard.

KIRK "DONKEY" MOBERT, who started the first Rocket Mass Heater online forum 10 years ago. In the true spirit of open source, it thrives, encouraging experimentation, inquiry, and base jumps. He's enormously generous with his time and expertise. Thank you Kirk.

ERICA WISNER, physicist, RMH instructor, innovative analyst and communicator, the perfectly balanced partner of...

ERNIE WISNER, wild man, strongman, storyteller, supporter and friend of Cob Cottage and the RMH project for almost a decade. Both Ernie and Erica teach together around North America and live so close to Canada that on a clear day they can see the polar bears. Thank you Erica and Ernie

Oh, about height. Just kidding, even tall people are okay, really.

Photo: Leslie Jackson

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Third Edition Notes: This book was first published in 2004, under the title *Rocket Stoves to Heat Cob Buildings.* This Third Edition continues the story of Rocket Mass Heaters, with improvements in construction instruction from our experiences, as well as results of experiments by people who are building and tinkering with them. All of the text is a collaboration between Ianto, who is a codeveloper of Rocket Stoves and the developer of Rocket Mass Heaters, and Leslie, who organized, typed, edited, and above all, got us into print. We tried hard to clarify the authorship of different parts—Leslie's icon sketches in some of the headers might hep. If it's still unclear, our apologies, but we're sure you can figure it out.

Rocket Mass Heaters are in a family of efficient wood-burning stoves called Rocket Stoves. What these various types of Rocket Stoves all have in common is that they burn small-diameter wood fuel in a high-temperature combustion chamber with an insulated internal chimney. The Rocket Mass Heater is distinguished from the Rocket Stove by a Thermal Battery (usually an earthen bench, floor, or bed) that stores the heat. The other thing Rocket Stoves all have in common is innovation by "the folk process." Rocket Stoves are improved upon not by engineers in a lab but by people like you, tinkering in your workshops, stacking bricks, lighting fires. Although these stoves can be built well with expensive industrial materials, Ianto says, "I'd like to address the people determined not to use a lot of money."

In this book, you'll find a basic recipe for building a Rocket Mass Heater. Why basic? Because your stove will be made to your local climate specifications, in your unique house, and with materials you source according to luck/whim/opportunity/dumpster-diving law, or if nothing else, money. Your inventiveness is an important ingredient in that basic recipe. Most readers with an adventurous, creative mind and a grasp of how wood burns can build one using the book by itself, and there are lots of resources online—both trustworthy and not—for additional inspiration. We highly recommend experiencing in person the comfort of a well-heated and well-designed Rocket-warmed bed or bench and the sound of the stove gently purring away. It truly is the nicest way to be cozy.

Check out the book's website (www.rocketstoves.com) or call Cob Cottage (541-396-1825) to find out about local workshops, to buy books, or to join online forums and share designs with fanciful and brilliant stovers striving for simple, efficient, comfy warmth.

The widespread success of this little book has been due solely to word-of-mouth propagation by you the readers. Without ANY overt advertising, review copies, or commercial distribution, over 40,000 copies of *Rocket Mass Heaters* are in circulation. It has been translated into French and Japanese. Spanish, German, Chinese, and Russian translations would be most welcome. This book's popularity is an indication not just of its simple clarity, nor of how delightful Ianto's illustrations are, but of how thirsty the world is for this kind of do-it-yourself tech.

—Leslie Jackson

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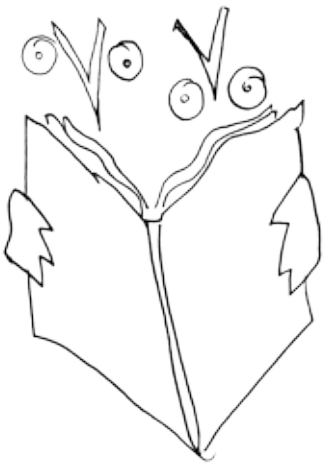

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Planting Seeds of Fire

Introduction by Kiko Denzer

This book is a gift (even if you did pay for it). It has planted seeds of fire and seeds of freedom, insight, and inspiration for many; some of them have learned to take better care of themselves and their families, started businesses, and grown as persons.

This edition includes some of their stories, some from the other side of the world. You can find others on the web (just strap on your seat belt and look up "Rocket Stoves" or "Rocket Mass Heaters"). Seeds scatter and get carried around to all kinds of unlikely places; the gift grows, and moves, and comes around again.

When you learn to provide your own basics, like food and heat, you gain an important freedom. Such freedom allows you to follow your own best motives. For me, freedom and my association with this book began before the authors wrote it.

I had already quit my day job when I took a workshop from Ianto about 20 years ago. He shared skills and knowledge of earth, fire, and building. I left and built a couple of wood-fired earth ovens (simple masonry heaters) for family and friends. People liked them so much that it launched me into many rewarding years of building, teaching, and learning; it also introduced me to a community of marvelously creative and practical people.

Ianto exemplifies the truth that "wealth consists not of having more, but of needing less." I was making my own bread and learning to grow my vegetables. I converted a friend's cabin into a house and built a cob studio that I heated with a Rocket Stove. My knowledge and confidence (and my teaching repertoire) grew. I wrote a little book about ovens, and it sold! And it grew into a little publishing company. Throughout it all, "rocket science" has helped keep me and my family warm.

One gift leads to another, and to keep it going, you have to give back. It helps, I think, if you don't go too professional (in other words, if you can work for love and not just money).

Here's a related story, this one more historical:

David Lyle (a teacher I have never met—see his wonderful *Book of Masonry Stoves*) tells the story of masonry heaters, which (like Rocket Mass Heaters) burn wood in a sensible, comfortable, and (arguably the most) environmentally appropriate way:

> According to Alfred Faber [a German historian of heating technology], the great innovations in stove design during [the period in which masonry heaters were developed] seldom came from specialists in the field.... "Homeowners," Faber found, "often experimented for years on their own stoves to reduce wood consumption. Their discoveries have appeared in hundreds of reports, books and journals. Among them almost all professions are represented: government officials, priests, monks, doctors, pharmacists, mathematicians, professors of all fields, but also painters, architects, merchants, manufacturers, diplomats, military men..." [from Alfred Faber, *1000 Jahre Werdegang von Herd und Ofen, Abhandlungen und Berichte*, Vol. 18, Deutsches Museum, Munich, 1950.]
>
> …Once the idea of baffles and smoke passages got about, many experimented with them and in ways of almost infinite variety.... It is almost fair to say that if you can imagine a winding smoke path within it, then someone, at some time in the past, has already built it.

I repeat this story (again), not because Rocket Mass Heaters are a new way of "imagining a winding smoke path," but because I think it illustrates how creativity comes from free and independent actors—people whom homeownership has freed from the need to specialize, to comply with outside rules, and to follow sometimes paralyzing "professional standards."

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Not that there's no place for good professional work and responsible, reliable, trustworthy craftsmen-for-hire. Indeed, people are now fabricating and selling heater cores and other hardware so more people—who may not be tinkerers or homeowners—can easily make a reliable stove and thereby increase their own freedom for other pursuits.

No, the point I wish to make, and the reason for offering this book, is not to provide you with a fail-safe recipe for the perfect stove—rather, it's an invitation to participate in the processes that make life worth living; the processes of growth and change, learning and doing and learning, receiving and giving.

These processes make up the source and purpose of life. Our ancestors knew them well; they give us science (from which we harvest knowledge), art (from which we harvest harmony), and religion (which means "to tie back" and from which—whatever our beliefs—we harvest continuity).

They all start with fire.

And they all come, like fire, with risks and responsibilities. With that in mind, before I leave you to your pyromania I'll refer you back to one last (old) story: Prometheus and Pandora.

They are usually told separately: Prometheus brought fire to humankind; Pandora brought sorrow and grief. But in truth, it's all one story. Old Zeus made Pandora to be Prometheus' wife, as part of a trick to pay Prometheus back for stealing the fire of the gods and giving it to man. But Prometheus suspected something and spurned Pandora. Instead, she married his brother, Epimetheus.

The brothers were themselves gods, who had fashioned (from clay, of course) all the creatures of the world. But while Prometheus took his time making man in his own image, Epimetheus, whose mind wasn't so quick as his hands, made all the other creatures and gave them all the gifts they needed to survive—teeth, claws, wings, horns, speed, strength… So when Prometheus finally got his humans done, there remained no gifts. To make up for it, he gave them god-like creativity—and fire. Of course Zeus was pissed!

We're usually told that Pandora "willfully and ignorantly" opened a box containing all the woes of humankind: pain, suffering, disease, anger, conflict, etc. But "Pandora" means "all gifts." What Zeus gave her made human society possible: the gifts of pottery, of cooking, of weaving, of beauty—and desire. From those primal aptitudes we make civilization—an edifice built with our tool- (and fire-) wielding hands.

At this point, however, I suspect more than what we've always been told. I suspect Pandora opened not a box but a jar (jars precede boxes in the archaeological record). I also suspect the jar contained Pandora's most important gift. Firstly, it embodied the essential art of pottery—which transforms (by fire) mud into permanent, impermeable ceramic. Secondly, I believe what it contained was not plague but knowledge—of consequences, and responsibility.

When we manipulate our environment, make tools, and use them for our own purposes, we have to live with the results, which include beauty, wealth, and comfort but also greed, conflict, and destruction.

Those who blame Eve and Pandora for bringing down "the wrath of God" on our heads forget that we owe our lives to wise, competent women and the partnership that creates life. Without knowledge of consequences and responsibility, we have no freedom.

The moral of the story, to me, is "go slow, pay attention, be careful." No gift comes without consequences.

P.S. A book is never a complete authority. This one has helped coalesce a wide-ranging community of people, many of whom are more than willing to share what they know and help you understand what you're doing. It's easy enough, now, to search the web, make a phone call, write an email, etc.

Welcome to the Rocket party! And good luck.

—Kiko Denzer, author of *Build Your Own Earthen Oven*. (See his case study on page 112, and find him on the web at www.handprintpress.com.)

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What This Book Is About

This little book is about comfort. And it's about achieving comfort with a revolutionary concept in wood-burning stoves that ensures almost completely clean combustion with very efficient use of the heat produced. Rocket Mass Heaters are still experimental in that construction information was first published only in 2004, but some have performed well in daily use for more than a decade. Ianto has used them for his only heat source since the 1980s. In most cases, they were inside a cob cottage, but one was in a fancy passive-solar wooden rental (for details, see *The Hand-Sculpted House*, the basic reference on cob building). They save a lot of fuel and completely rearrange our concepts of house heating, wood burning, and dependency on coal, oil, hydro-, or nuclear power for our comfort. Rocket Mass Heaters can be built at home with simple tools by relatively unskilled people. Although they are well-suited to earthen buildings with thermally massive walls, floors, and built-in furniture, they can be built into any kind of structure.

The term "Rocket Stove" has been used loosely for about 25 years to mean a fairly wide range of combustion devices used for cooking and heating.

Aside from the mass heater described in detail in this book, Rocket principles have been variously applied. Larry Jacobs and Ianto came up with a version using only a metal drum and two stovepipes, later called the Pocket Rocket (see Detroitus & The Pocket Rocket page 81). Then, in the late 1980s, Ianto helped develop a lightweight concrete single-pot cookstove for urban Guatemalans. More recently, small portable cookstoves have been developed using tin cans and simple insulation. Experimental Rocket-fired ovens and water heaters have also been built.

Perhaps most significantly, Rocket Mass Stoves for house heating are now starting to appear all over the world and have real promise in that they improve comfort and reduce the amount of fuel burned, thereby lessening the load of carbon dioxide (CO_2)on greenhouse gases. They turn almost all their wood into heat, and can store almost all of the heat generated for optimal comfort when you need it.

Illustration: Leslie Jackson

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Who This Book Is For

This manual is intended for pyromaniacs: tinkerers, people with curiosity about fire, owner-builders, those with an experimental mind, do-it-yourself builders who want more independence from utilities and have environmental concerns, and above all, those who want to be snug at home. The realm of Rocket Stoves is an experimental one whose time is overdue. Play and innovation are highly recommended. As our friend Tom Frame says, "Don't be afraid to try something new or different. Don't have the right part? Try something else. Can't make a quick phone call for answers? Trust your own judgment. Just can't figure it out? Wait, be patient. Move on to something else if you can. The answer will come. Most importantly, don't rush this thing! You really want it to work when you're done building it. Take the time needed."

We can't emphasize enough that you build your stove outdoors and run some experiments with it before rebuilding it indoors. And if your intention is to invent a new stove based on these principles for your particular situation, build the 8-inch model presented in this book first. You won't regret it. The model of Rocket we describe suits the Pacific Maritime climate very well, but it is not limited to it. Once you understand the principles of the Rocket Mass Heater, best done by actually building one, and then enjoying it warming you, you'll be able to modify it to your own heating needs.

Rocket Stoves' design is exploratory; their use is experimental. The attention they demand may keep you fascinated or you may find their quirks irritating. We look forward to hearing (and learning from) your feedback, comments, stumbling blocks, epiphanies, and wild fancies. Fire away, so to speak. You'll find discussions and workshops throughout the country and increasingly, the world. We're here to help you find regional sources of materials, workshops, and fellow stovers, so stay in touch, and good luck with your stove.

As with most reading, its value is multiplied by discussion with other readers. There are online forums such as donkey32.proboards.com, but nothing's as good as face-to-face discussion.

If you're building or tinkering, find a buddy to work with. You both can read the same sections of the book. Telephone works pretty well, as do letters, both a lot more personal than electronic intermediaries.

Building wood-fired heaters is serious business, as fire is risky, which is why there are building codes around it. Some websites and online videos make the claim that these stoves are 99% efficient, for example. Others make the stove look as simple as baking a cake—though as dangerous as a bomb—in an afternoon. As our friend Max Edleson says, "I am weary of fanaticism, especially around novel ideas. I think that the Rocket Mass Heater, in its exciting and relatively quick appearance over the internet, has suffered some from this, particularly through claims of its miraculous performance and perfection, all at an unbeatable price! Their daily use shows that they might be the perfect solution for some situations, but not at all for others."

Kiko Denzer agrees. "Corners are being cut a bit too close for safe comfort with some constructions I have witnessed online. Some builders seem awfully *laissez-faire* about the dangers of temperatures and combustibles. I am amazed that houses haven't burned down. Ianto's technical, but only until he's convinced you that you can make your own heater and save a lot on fuel expenses. After that, you can find him in the garden."

Exercise caution not only in building and operating your stove, but also in your research!

THE FINE PRINT

Neither Ianto Evans, Leslie Jackson, nor Cob Cottage Company can be held in any way responsible for damage, fire, or injury arising from the use of this book. These stoves are experimental, and besides, we don't have any assets. So, enjoy full freedom from fire damage and injuries by exercising common sense. (For some precautions, see Fire! Fire! on page 75.)

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The Combustion Unit...

Photos: Leslie Jackson

...is connected to the Thermal Battery.

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Photo: Max Edleson

This Rocket Mass Heater in Argentina, built by workshop participants led by Max and Eva Edleson, sends its gases down an adobe brick passage within the bench. (See the story of this heater in Case Studies, page 97.)

Photo: John Santiago

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Photos: Art Ludwig

Art Ludwig's Rocket Mass Heater in Santa Barbara, California, is a cozy booth. (His case study is on page 104.)

Photo: Art Ludwig

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Photos: Leslie Jackson

Kirk "Donkey" Mobert's mud guest hut on the Northern California coast (see his case study on page 94).

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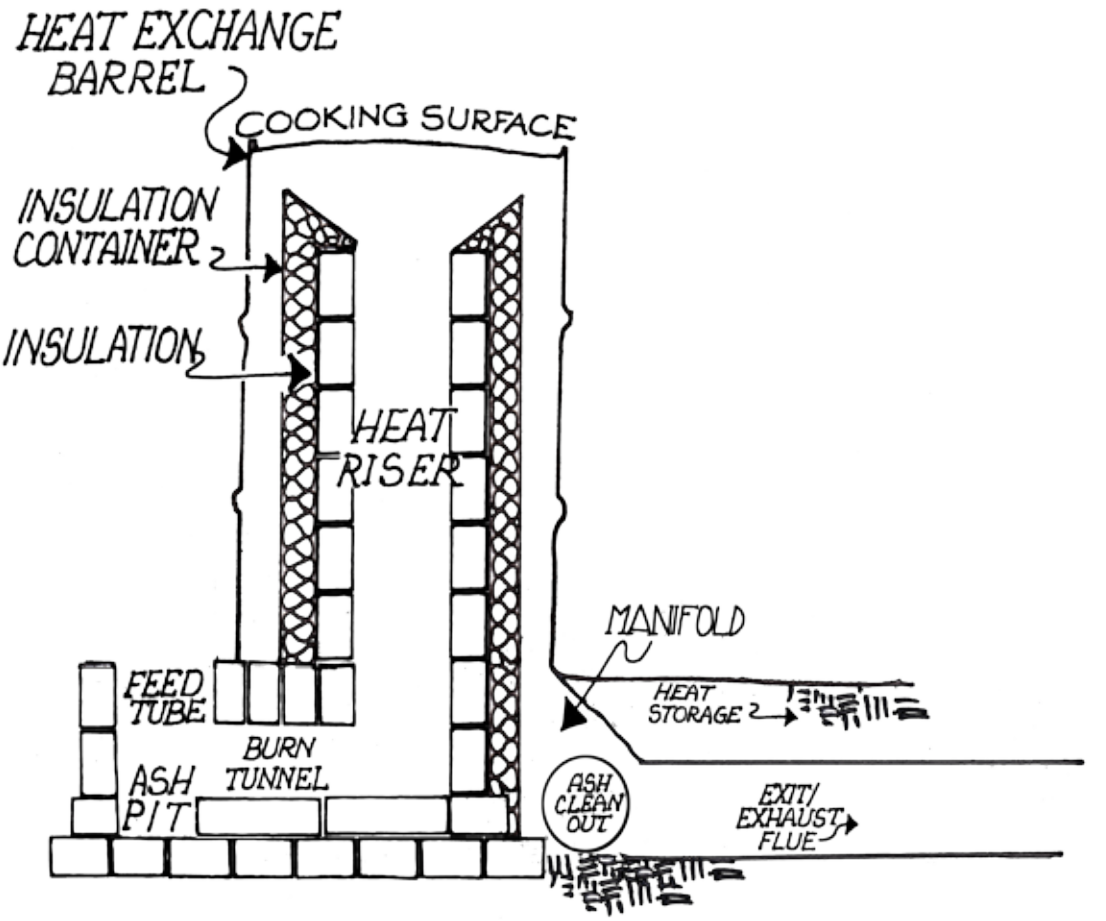
Combustion Side of a Typical Rocket Mass Heater



<== *Combustion Unit Heat Storage* ==>

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Why Rocket Stoves?

Rocket Stoves grew out of work I did between 1976 and the late 1980s on solutions to the international firewood crisis and smoke problems in the homes of traditional people. In Guatemala in the 70s, I helped work on the Lorena Stove system, which uses a sand-clay amalgam to contain the fire, hold up the pots, and store surplus heat. It rapidly attracted worldwide attention and is now widely used in Latin America, Asia, and Africa. Later I worked in over 20 countries as part of a team that helped people create better cooking facilities. I spent much of a decade in villages, in people's homes, mostly with the women who actually do the cooking. One result of my experience as a professional pyromaniac was some work in the United States on the challenge of improving wood-fired heating stoves for cold climates.

By 1980, woodstoves had scarcely improved since Franklin. The basic format had always been a simple metal box with an attached exhaust pipe. The higher the stack temperature, the better the stove draws air through the fuel. To a point, the more heat lost out the top of the chimney, the better the combustion. Clearly, this is wildly inefficient. The sky has no interest in being heated. The stove also heats the air surrounding it, which rises to heat the ceiling, gradually circulating as it cools. To be optimally heated, you would need to be perched on the ceiling directly over the stove.

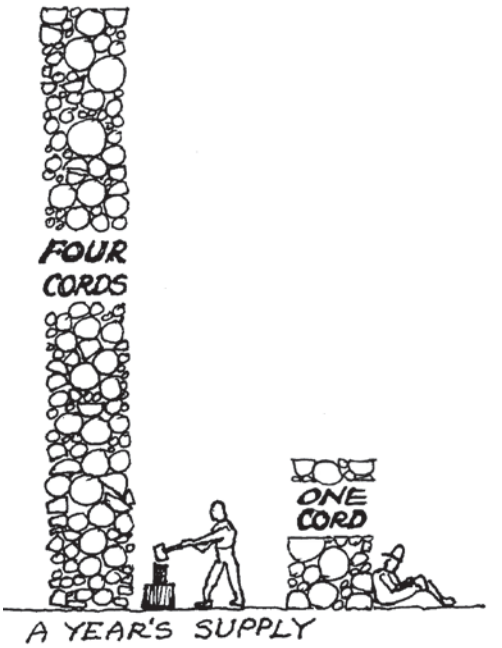
Worse, most woodstoves burn very imperfectly, that is, not all the energy available in the wood turns into heat. Much of the wood's potential heat leaves the stove as smoke: particles and unburned gases. The results include poisoning your downwind neighbors, excessive firewood use, more CO_2 heating up our planet, and personal frustration. Clean air standards imposed by the federal government in the 1980s attempted modestly to limit the amount of smoke and particles put out by commercial woodstoves, but came nowhere close to ensuring clean burning.

Our goal in developing Rocket-type stoves was to rethink completely the question of how to burn wood inside a house to improve human comfort, use less firewood, and cut pollution.

The results are impressive. In my own cottage I burn only about 1 cord of (fir and alder) firewood a year, while my neighbors average 3–5 cords—granted, their houses are much bigger than mine. You can usually tell when any of the neighbors are around by the clouds of smoke coming out of their chimneys. By contrast, we burn so clean that visitors coming into my house want to know how come it's so snug without the stove burning. Imagine their surprise when they learn that in fact, it is burning merrily.

As I write, I sit by my own Rocket Mass Heater in my little cob house in the depth of the Oregon winter. I built this stove myself in a day from recycled parts that cost less than $50.

Since the late 1980s, Rocket Mass Heaters have been our only heat source apart from the sun. I have daily been able to evaluate these heaters that suit me better than anything else I can find.



A comparison of a year's supply of wood. The left stack is my neighbor's, the right is mine.

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Significant Features of Rocket Mass Heaters

1. The emphasis is on **human comfort**, not on heating a building.

2. The Rocket Mass Heater has two conjoined parts:
The Combustion Unit, which burns briefly but very hot, and the Thermal Battery, or heat storage in a heavy mass, where it can be released when needed for hours or days after the fire has gone out.

3. The insulated high-temperature chimney / afterburner, which generates the draft to supply combustion air, is inside the stove itself.

4. The firewood stands upright and burns at its bottom end only, feeding the stove by gravity as it falls into the fire.

5. They offer extraordinary efficiency, both in extracting heat from the fuel and in delivering heat for use when and where it is needed.

6. They are easy to construct from inexpensive materials, without special tools.

7. They have the capacity to push heated gases through long horizontal passages in floors, beds, or benches.

8. Note the concept of separating the Combustion Unit from the use of the heat so produced, and particularly, storing that heat for hours or days in inexpensive built-in furniture.

9. By attaching the Rocket Stove to a heat storage device, we are able to soak up the heat from the exhaust gases and store it while the stove is burning, then release it slowly as needed, over quite long times (and long after the fire has gone out).

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HOW WOOD BURNS

The air we breathe is about 20% oxygen. Oxygen is super-reactive and combines at the right temperature with almost anything and burns it, releasing heat. Different materials catch fire at different temperatures. For instance, phosphorus burns just by exposure to air at room temperature, but steel needs to be heated to thousands of degrees to burn. When wood is first heated, the lignin and cellulose that comprise most of its bulk break down into a wide range of simple to complex chemical gases. When each reaches a certain temperature, it ignites and burns combining with oxygen and producing flames, in a process known as *combustion*.

Watch a piece of firewood throughout its burn cycle, from when heat is first applied all the way to ash. First (a), you'll notice steam and pale visible gases squirting out as they reach boiling point inside the wood. Then (b), there will be smoke, blue or grey or sometimes black, difficult to breathe, smelling toxic (it is). Gradually (c), as the outer parts begin to glow, the smoke catches fire. Then finally (d), glowing coals, no smoke, no big flames, only little blue ones as those coals burn.

You just watched (a) the wood heating up and drying out, and (b) the volatile oils boiling out as cellulose and lignin *pyrolyze* (break down under heat) into other chemicals, hundreds of them. The charcoal that remains begins to glow as it too burns (c), giving off carbon monoxide (CO). When conditions are hot enough, the smoke catches fire with long yellow flames, turning itself into carbon dioxide (CO_2) and water vapor, and of course also giving off heat. When (d) the smoke is all gone, coals remain, glowing. Those short blue flames you see are the CO burning and thus bonding with oxygen to create CO_2 and produce again more heat.

If there is not enough oxygen, combustion will be incomplete, producing smoke and CO and, of course, less heat. The same happens if the burn zone is too cool. Campfires often smoke at first for lack of heat, but they also smoke if you restrict their airflow with wet leaves or by shoveling dirt on, etc. The perfect stove has just enough oxygen, dispersed through the smoke gases, and a high enough temperature that everything burns down to only water vapor, CO_2, *heat,* and a little ash.

Given the notoriety of CO_2 as a greenhouse gas, people are sometimes shocked to hear that the Rocket Stove generates CO_2—yet any woodstove, even burning cleanly, will produce CO_2, as will a coal-, oil-, or gas-burning power station, or a car using gasoline. But the cleaner we burn wood, the less wood we need, because we're burning it more efficiently, thus creating less CO_2. To be responsible, we need not *to stop* burning hydrocarbon fuels, but *to reduce* their use. This is a good reason not only for clean-burning woodstoves but also for smaller houses, passive solar homes, snugger spaces, heating our bodies directly by contact, and not heating anything that we don't need to—empty parts of the house, or the atmosphere, for instance.

For a detailed, readable further discussion, see *The Woodburner's Encyclopedia* or *Heating Your Home with Wood* (see Recommended Books).

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HOW HEAT MOVES

Heat is forever redistributing itself, the warmer parts of the universe constantly attempting democracy by generously heating their cooler surrounds. Anything warmer always tries to heat something cooler. If the temperature difference is great, the heat flow is faster, though impediments to heat transfer (insulants) always slow it down. Remember that heat flows from warmer to cooler by three separate modes: *radiation*, *convection*, and *conduction* (heat rays, rising gases, and contact heat).

Radiation is the direct transfer of energy through space. Sometimes it comes in the form of visible light, for instance sunshine. Often the wavelength is shorter or longer than the visible spectrum and therefore invisible to us, as is the radiant heat from a metal woodstove. Sometimes it's a mixture, as at a campfire, or when you look down into the toaster (which is a totally radiant heater with both visible and invisible rays singeing your bread).

Radiation moves in straight lines, in every direction, up, down, and all around simultaneously through space until it meets a solid, where it is reflected and absorbed in varying proportions. Some surfaces such as polished aluminum reflect a high percentage. Skin, on the other hand, absorbs a much larger share—happily if you're cold but rather unfortunately if you're too hot.

Knowing all of this is useful if you are building a campfire, which heats you only by radiation, or operating a toaster, which is a radiant cooker. As a way of being comfortable, however, radiation has drawbacks. An obvious one is that it heats only exposed surfaces. Your front can be overheated while your back is freezing, and clothing may prevent a true radiator from heating you at all. To radiate best, metal stove surfaces need to reach dangerously high temperatures, and as the radiant surface changes temperature with the complexity of wood burning, you have to alternate moving closer and backing away to stay comfy.

The **amount** of radiation received increases disproportionately with a hotter-radiating emitter and lessens corresponding to the square of how far away you are. Twice as far away, you get not half but a quarter of the effect. If you get twice as close to a hot stove, you get about four times as much heat. Also, a radiant surface loses disproportionately more heat as it warms up, so a *slightly* warmer metal stove heats you a *lot* more.

Convection is heat transfer by the bodily movement of a gas or a liquid. Smoke rises if it is warmer than the surrounding air. Peer into a clear glass of hot cocoa or miso soup and you will see a lot of movement as the warmer liquid rises and the cooler falls. It's all convection.

As a mode for heating people, convection isn't all that useful. To be warmed by convection, you need to be above the heat source. The best place to be comfortable with convective heating in a house is usually against the ceiling where the warmest air ends up, and optimum convective heating from a fireplace would have you located in the chimney.

Also, be aware that we often mislabel. A "convection oven" isn't—it has a fan. Another misnomer is the "radiators" under windows that heat public buildings, which are really convectors. They can't get hot enough to be effective as radiators, being too far away from most people. Most of their heat is actually carried upward—convected—with the air they heat by conduction.

Conduction is heating by contact. When you hold another person's hand, if you think he/she has a cold hand, it's because you're donating some of your body warmth. As with all heat transfer, conduction always flows from hotter to colder, however small the difference may be. If the surroundings are a uniform temperature, heat flows equally in all directions, all around and up and down. "But doesn't heat always rise?" No, only by convection. Heat rising is not a special characteristic of either radiation or conduction.

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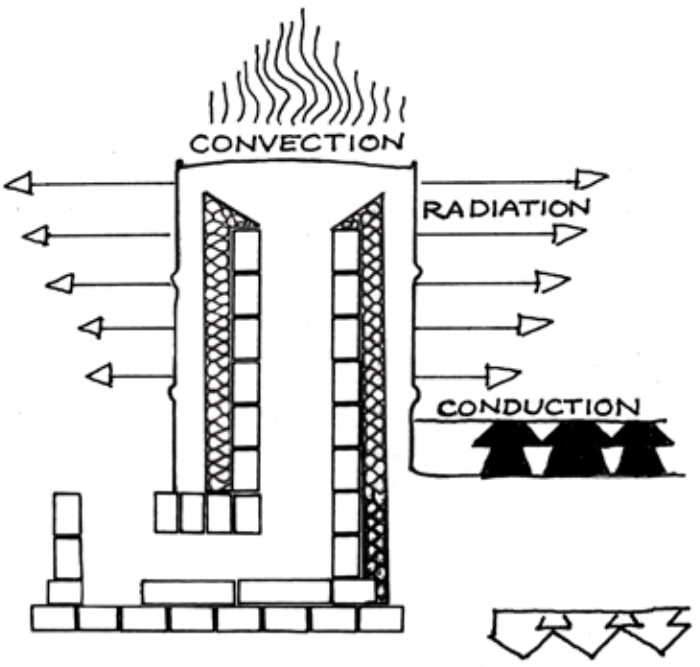
Conduction is most apparent through solids, depending upon how well the solid allows heat to pass through it. Efficiency of heat conduction varies a lot, from that of still air, which is extremely low, to that of metals (sit on an aluminum chair on a cold day). Masonry materials are somewhere in between. The denser they are, the faster they transmit heat. Limestone and brick are medium-fast conductors; granite and basalt are faster; iron ore would be even faster, because it's heavier and contains metal. Denser materials and those that contain metal can be dangerously conductive, such as hot stones straight out of a campfire or a cast-iron frying pan's hot handle.

In houses, conduction is rarely used for personal comfort, though it is generally the most effective way to warm up. Fireplaces give us no conducted heat at all, as the warm parts are all far too hot to touch. The same is true for most metal box stoves. Most houses have only one conductive way to warm up fast: take a hot shower. Or try hot water bottles, electric blankets, and hot tea. Cuddling with someone warm is useful but not always practical.

Insulation, or how heat doesn't move. To delay heat moving by conduction, a good rule of thumb is to choose the most lightweight material available. Lightweight usually means there is air trapped in it. A down parka, sheep's wool socks, or a fiber-filled bed quilt all contribute to our comfort by trapping air, one of the most effective insulants known.

At high temperatures, most biological insulants either burn or fall apart. Foam boards melt and off-gas dangerous toxins. So for stove construction, we use mineral insulants such as pumice, vermiculite, or perlite. Clay is less insulating, so in clay-insulant mixes, we use as little clay as possible.



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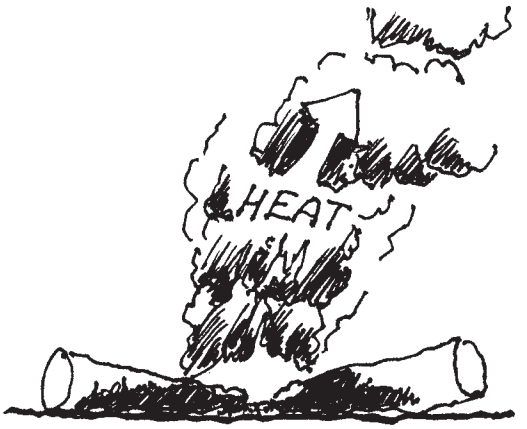
Draft Works the Stove

CAMPFIRES

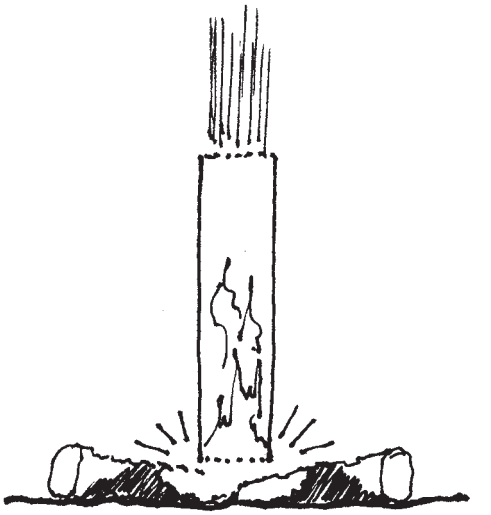
A campfire burns wood in the open air, outdoors. Its combustion success depends upon a steady flow of air.

To warm up by a campfire, you can't heat yourself by contact; the coals are too hot. You would get burned, and if you were to sit in the hot gases trying to warm up, you would be slowly smoked and asphyxiate. For heating people, only direct radiation is available, from the coals and flame. But most of the heat is normally wasted. You can only warm up *beside* the fire, not too close.

An open fireplace in a house is just an indoor campfire and can only heat you by radiation.



Campfire heats mostly by radiation.



Try a simple experiment: Hold any kind of cardboard or metal tube over a smoldering campfire, tight over the embers. The fire will immediately come to life, the embers will glow brighter, and the smoke will lessen. It will burn better.

CHIMNEYS

Chimneys draw air up inside themselves because the gas in them is hotter than the outside air surrounding them. The draw is dependent on both the height and the (average) interior temperature: height multiplied by heat. So you can get the same effect from a very tall, rather cool chimney (as in most factories) or conversely, from a short, very hot chimney. A 100-foot-high chimney that is 20°F warmer than the surrounding air generates roughly as much draw as a chimney just 2 feet high but 1000°F hotter.

WOODSTOVES

A woodstove is a fireproof container with a fire inside it. For oxygen to be drawn through the fuel, a chimney carries hot gases up, drawing cooler air in past the fuel (and perhaps through the house). Hopefully, sufficient air is drawn in, or the fuel merely pyrolyzes—that is, the volatile oils bake out without burning—producing smoke that lacks sufficient oxygen to be burnt. By contrast, if too much cold air is coming in, the surplus air dilutes the hot gases in the chimney and lowers the temperature in the stove, making the burn worse. For the whole thing to work, the chimney must be hot, so valuable heat is always lost from the building to the sky.

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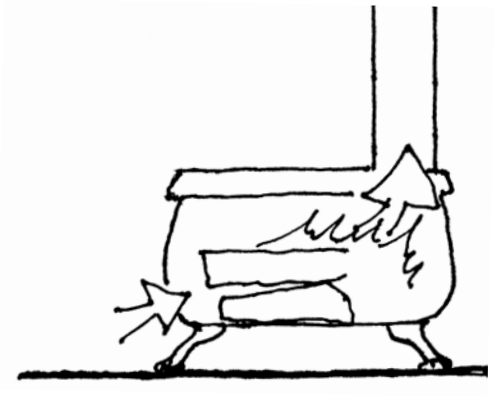
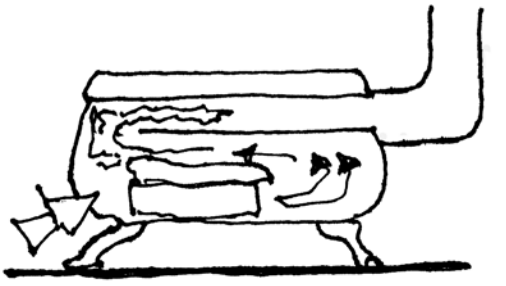
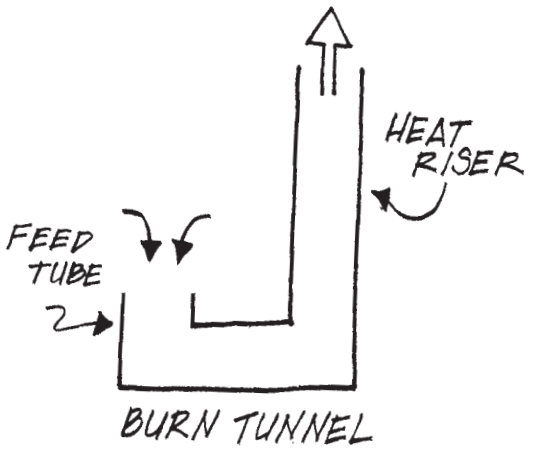


A metal box stove is an advance over an open fire, but still wastes a lot of heat up the chimney.



With a shelf damper, the situation is better: a cleaner burn and a lower exit temperature, so less heat leaves the house.



Essential Parts of a Rocket Stove

The core of the Rocket is a J-shaped tube with square corners, as shown. The fuel falls down the short leg of the J, which is called the Feed Tube. Burning mostly happens in the horizontal part, which we call the Burn Tunnel, and the flame path extends up the long leg of the J, called the Heat Riser.

Rocket Stoves Are Different

The revolutionary part of Rocket heating stoves is the concept of **putting the chimney** (the Heat Riser) **inside the stove**. This is done by enclosing the Heat Riser so exhaust gases are captured with almost all the heat still in them. Then, by running these gases through a masonry (or water) mass, they are encouraged to give up most of their heat before leaving the building.

The stove inside Ianto and Linda's house has an internal chimney about 3 feet high, which runs at 1200–1800˚F. The metal barrel that surrounds the chimney loses enough heat that the combustion gases are down to perhaps 500–700˚F by the time they leave the stove. But now instead of wasting that heat by discharging hot gas from the house, it is fed through a cob and rock daybed so more of the heat is captured inside the building.

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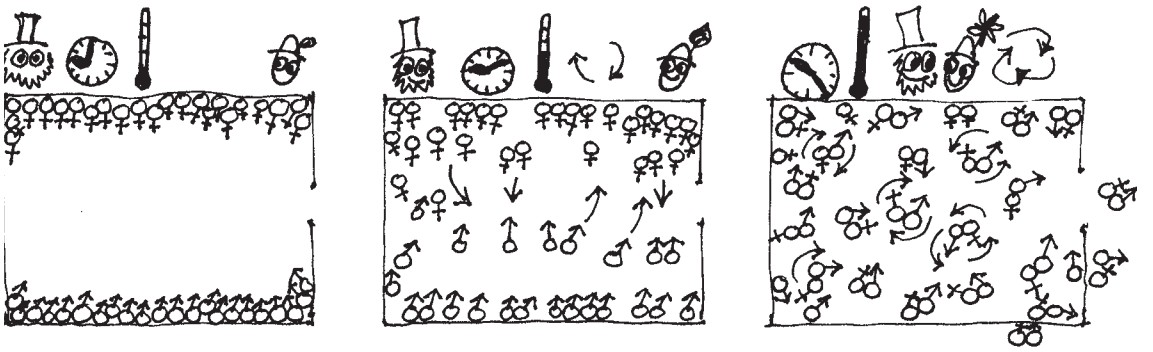

Time, Temperature, Turbulence: A good fire is like a barn dance. Good clean fun!

The Three Ts

In seeking a clean burn, think 3-Ts: Time, Temperature, Turbulence. The molecules of oxygen and of the combustion gases all need to be able to find each other as well as mix together well. It's like one of those huge country dances, where all the men line up on one wall, and all the women on the opposite one. When the music begins, everyone surges onto the dance floor, looking for a partner. For everyone to pair up, the tune needs to be prolonged (time), the music fast (temperature), and the dance rambunctious (there's your turbulence).

So to be most efficient, a Combustion Unit needs an **insulated** combustion chamber (to maintain the dancers at a high temperature), a **tall** enough Heat Riser that all the oxygen is used up (as the hot, lightweight dancers strut and spin their way up), and a non-streamlined profile to **tumble** the gases (shakin' their boogilators). Hence the **abrupt right-angle turns** in a Rocket Stove's interior.

Unlike a conventional woodstove, Rocket Stoves don't need to waste heat to ensure a burn. The Combustion Unit at the core of a Rocket Stove turns wood into mostly CO_2 and water vapor with a little wood ash and a lot of heat. How we use that heat is a separate story.

COMFORT THROUGH STORED HEAT

Even with the wood burning at 100% efficiency, if we waste the heat by not using it, efficiency is moot. The cleanest-burning conventional woodstove with a platinum afterburner may well burn all the wood cleanly, but to function at all, it needs to waste a large proportion of the heat generated by discharging it up the chimney.

Whereas with most woodstoves the chimney sucks cool air through the stove and pumps hot gases *out of the building*, the Rocket Mass Heater *pushes* hot gases that we can guide and control to **direct the heat to wherever we need it.** We can cook with it, or heat our houses, or heat water.

The Thermal Battery

The Rocket Stove is a "thermal pump" that shoves out hot gas, which can be used to heat built-in furniture. It can easily push hot gas through 30–40 feet of horizontal pipe, storing heat in the interior walls, the floor, or the seating. By sitting or lying on a heated seat, your body is warmed directly wherever it makes contact. You also bask in the warm air rising from that seat as it circulates through the room. In Ianto's house, people can comfortably do paperwork while sitting on the bench that the Rocket Stove heats when the room temperature is only in the 50s. In contrast, to be comfy by heating

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all of the air in the building equally, air temperature would have to be in the 70s. Rocket Mass Heaters take what would otherwise be wasted chimney heat to warm built-in furniture such as beds, couches, and chairs, as well as floors and interior walls. They can *store* that heat for when it will be needed.

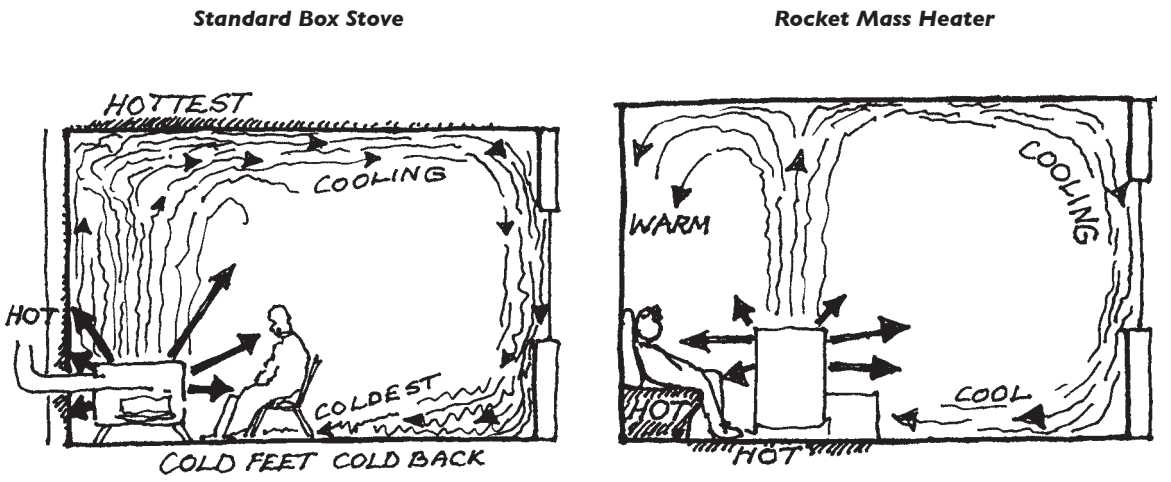
We live in surprising times. Every so often we wake up to debunk a societal myth that we have accepted all our lives. The myth that *houses need to be heated* permeates North America, and society has encapsulated this obvious fable into law. Building regulations have prescribed that whether we're home or not, every single corner of the interior of the house should be heatable to an equal 70˚F. Most of us have been tricked into this nonsensical situation by a gigantic corporate cartel that includes the whole energy industry, furnace manufacturers, architects, and the enforcers of building regulations. They all profit from our squandering the last of our grandchildren's inexpensive fuels and working for somebody else to pay for it.

Let's be clear. Provided we don't let the water freeze, the house could not care less whether it is heated. The inhabitants are the only beings who count. We want to heat people, not houses. Once we understand this, the situation gets much easier.

Houses heated by forced air or furnaces depend upon our bodies being in contact only with the warmed air inside the house. A house can contain an awful lot of warm air, of which only a very small proportion ever comes in contact with us. All of the other heat is effectively wasted. Air, being one of the best insulants, certainly isn't a fast or efficient way to warm up, and it escapes easily.

To warm up quickly, we need *contact* with something warm. In a house with only hot air available, our choices are: make a hot drink, jump in the shower, or cuddle up with a warm body. (Guess what my choice is!)

With a Rocket Mass Heater, we are able to soak up the heat from the exhaust gases and store it for quite long periods. The 3-ton double daybed attached to the Rocket Stove in the Cob Cottage office stays noticeably warm for about 3 days after 3–4 hours of the stove burning. It acts as a Thermal Battery, storing heat while the stove is burning, then releasing it slowly.



How Rocket Mass Heaters are different

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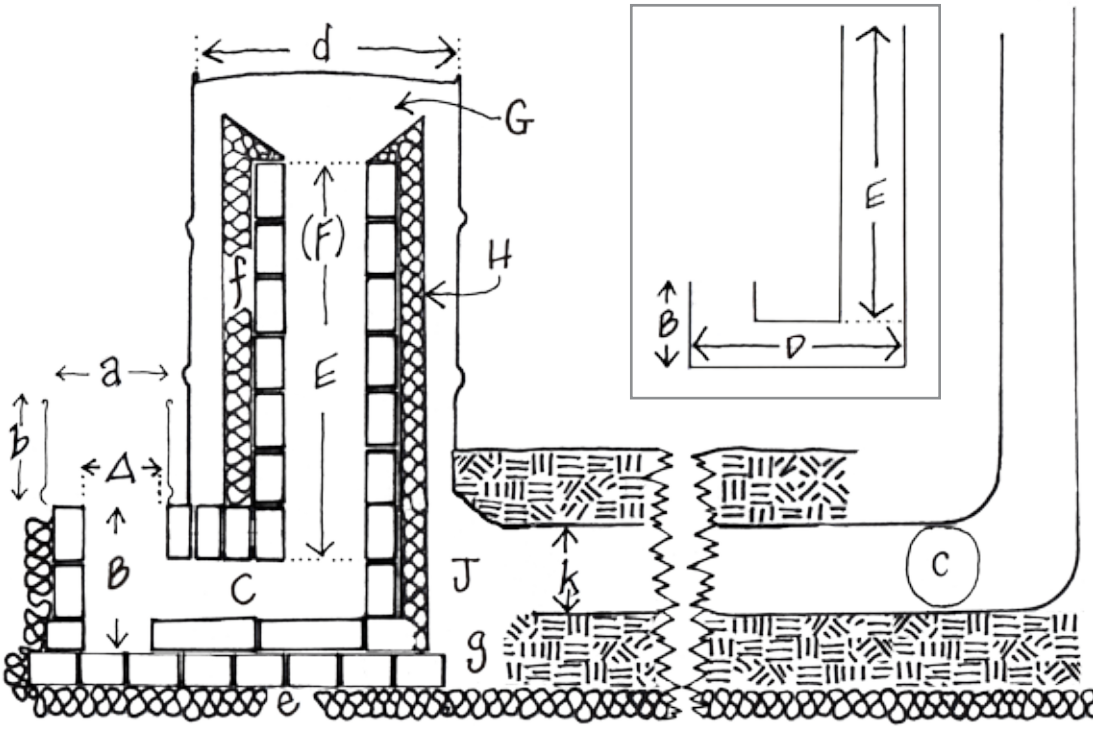

A few dimensions and relative proportions are critical to your Rocket Stove working at all. Some others are not crucial but are strongly recommended. The dimensions of critical importance are keyed in the diagrams on this page with large, bold capital letters. The cut-away drawing highlights the J-tube dimensions. Some dimensions are not important; we note that in lowercase letters. Throughout this section, we'll describe the dimensions and proportions of a basic downdraft self-feeding, cooking, and heating Rocket Stove with a 55-gallon drum heat exchanger and an 8-inch stovepipe flue. Refer to the diagrams and double-check all of the numbers and letters before you begin building.

A is the cross-sectional area of the **Feed Tube** (and **Burn Tunnel** and **Heat Riser**). It should be kept ***very tight***. Note that an 8-inch cylindrical pipe at **k** gives you about 50 square inches. The tube is best rectangular or square (not rounded) in cross-section. The cross-sectional area of **A** allows a hole about 7 inches square or 6 inches by 8 inches. (A 6-inch exhaust pipe can take about 6 by 5 inches [30 square inches] at **A**.)

B is the effective height of the Feed Tube. Whether there is an ashpit or not, it is measured from the bottom inside the Feed Tube to the top of the opening. ***Keep it short.*** The fire should not burn all the way up the Feed Tube. In a well-working stove there is enough draw to keep combustion to the bottom of that tube.

C is the cross-sectional area of the horizontal Burn Tunnel, normally made of brick, in which most of the burning happens. A single common brick on edge is about 4 inches high and 2¼" thick and firebrick is about 4½" x 2½", so arrange bricks flat or on edge to make up the required height.

C should be the ***tightest part*** of the "intestinal" system. The size of the cross-sectional areas of all parts of the stove's internal ducts ***should never decrease below that of C***. In other words, the cross-sectional areas of **F, G, H, J,** and **k** should all be greater than that of **C**. Make sure you keep the cross sectional areas of the exhaust stack, the horizontal flues, and the gap at the top of the Heat Riser bigger than the area of combustion at **C** to avoid bottlenecks that could slow combustion or

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back up smoke into the room. **D** is the length of the horizontal Burn Tunnel, as measured from the inside of the Feed Tube to the opposite end of the Burn Tunnel (see drawing insert, previous page), and should normally be as short as possible to minimize heat loss and increase the Heat Riser temperature. Optimum proportion is less than half the height of the Heat Riser. Longer tunnels need more insulation.

E is the most important single dimension: the height of the **Heat Riser** from the *top of the Burn Tunnel* to the top of the enclosed Heat Riser stack. (Measure this distance from the dotted line in the drawing on the previous page to the top of the Heat Riser.) **E** affects how much air the stove is able to suck through the fuel and therefore the rate of burning, the potential power output, the temperature of the cooking surface, and also radiant heat production from the sides of the barrel. Draw is proportional to height, so if **E** were twice as high, you would have about twice the draw. The height in the specimen 8-inch system shown is 33 inches, but could be about 25–50 inches.

F is the cross-sectional area of the Heat Riser and should not be less than **C**. The Heat Riser can be 7 inches by 7 inches square or 8 inches diameter round.

G is a little hard to describe. It's the height of the cylindrical gap between the roof of the Heat Riser and the inside top of the barrel. The total area of the walls of that cylinder should also be greater than the area of **C** to avoid slowing the gas flow at this point. With an 8" system, its height should be 2" at the least. Note the angle of the insulation cap at the Heat Riser's top. This slope is to prevent ash from accumulating there. Whether you slope that to the inside or the outside is not as important as getting that gap sufficient.

H needs to be at least 2 inches wide, preferably 3 inches. For heating from all sides of the barrel, we need to encourage the hot gases to swirl down all around the barrel, not just short-cut to the exit tube. But it's good to place the barrel eccentrically over the Heat Riser, with the gap slightly wider on the side where you want extra radiant heat and narrowest where you want the least.

J, the transition from barrel to tunnel, the "Manifold," is an easy place to unwittingly create a bottleneck. It needs to be bigger than you might think, with a cross-section at least twice that of **C**. *Make sure to bell out the cross-sectional area at this point, with a good deep ash pit at* **g** *so ash buildup doesn't constrict the flow.* Make the opening big enough to get a cleaning brush in. Flare the cleanout into the duct so you can reach your arm in there.

g is the ashpit, not more than 3" deep. Extend it a little bit into the Burn Tunnel. Build a cleanout/inspection hole at **g** for easy cleaning/troubleshooting.

K is the exhaust, the horizontal flue that carries hot gas through your floor, heated bench, bed, etc. This should be at least the stove's system size.

The following dimensions are less important, but please read the notes.

a is the diameter of the optional 10- to 16-gallon barrel that encloses the Feed Tube. **a** is in the region of 14 inches.

b is the additional height a Feed Barrel would rise above the Feed Tube. If you install one, keep it less than a foot high, or there's a danger that hot gases can accumulate in that space and reduce the efficiency of the draw. It is valuable—though optional—to install this barrel, which makes it easy to control occasional stray smoke, and to regulate the air input to the stove. It can also prevent small children from falling in, maybe, and allows you to fit in longer firewood when necessary. If you do choose to install a Feed Barrel, it is very important to not insulate it.

c is a primer/cleanout door. Put it as close as possible to the bottom of the vertical stack.

d is the diameter of the Heat Riser barrel. A standard 55-gallon is 22½" across. Twentyfive- or 30-gallon barrels work well with a 6-inch duct system, and a 55-gallon barrel does fine with an 8-inch system. The bigger the barrel, the lower and safer its surface temperature will be.

e is the insulation beneath and surrounding the Burn Tunnel. To keep the temperature in the Heat Riser as high as possible, you need at least 2"–3" of insulation here. If you wish to store some of the heat generated in the floor beneath the stove, leave out the insulation.

f is the insulation around the Heat Riser. Put in as much insulation as you have space for.

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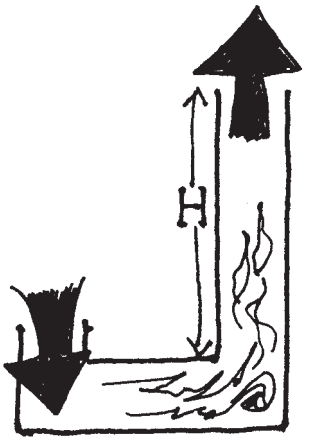
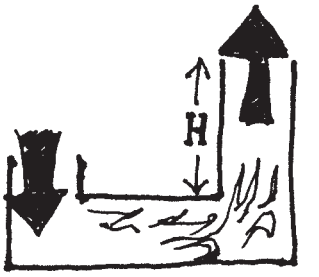
Relative Proportions of Burn Tunnel, Heat Riser, & Feed Tube

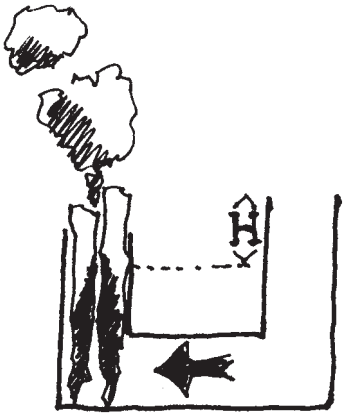


Burn Tunnel length is one-half of the Heat Riser height. This is ideal, creating twice the draft.



Burn Tunnel length is equal to the Heat Riser height. This is a problem; the Heat Riser should be at least twice the length of the Burn Tunnel.

Burn Tunnel length is twice that of the Heat Riser. Twice the heat loss from the Burn Tunnel; half the draft.



Feed Tube is too high relative to the Burn Tunnel and Heat Riser. Burn-back can happen with poor draft.

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THE COMBUSTION UNIT

The Combustion Unit for a system that uses 8-inch-diameter pipes measures about 4 feet long by 3 feet high by 2 feet front-to-back, though it can take up less vertical space if you sink the whole thing into your floor. (For sizes and proportions, consult the diagram on page 28.) Keep referring to it; some of the standards are critical. Make sure there is enough ceiling height above the burn unit to install the barrel over the finished Heat Riser.

For your first-time build, play it safe with an **established and tested model of the Combustion Unit.** The heat storage, on the other hand, can be custom designed to reflect your family's needs. Don't try a complete floor heater the first time around, but you have many options for heat storage in a snug corner, a heated bench, or a warm bed.

In very cold areas or with a house over 1200 square feet, you may need a bigger system altogether, including a larger barrel. There's probably a limit to how big you could build a Rocket without very specialized, high temperature materials. You don't want the whole thing to melt. Let us know your experience.

Placement of the stove in your house can determine where and how heat is available, how much is stored (or lost through walls or windows), and ease of stoking and fuel storage. For instance, a stove used a lot for cooking might be close to the food preparation area and one mainly for lounging—guess where—in the lounge of course! Carrying in firewood can be messy, so you can reduce floor sweeping by locating the Feed Tube close to a door.

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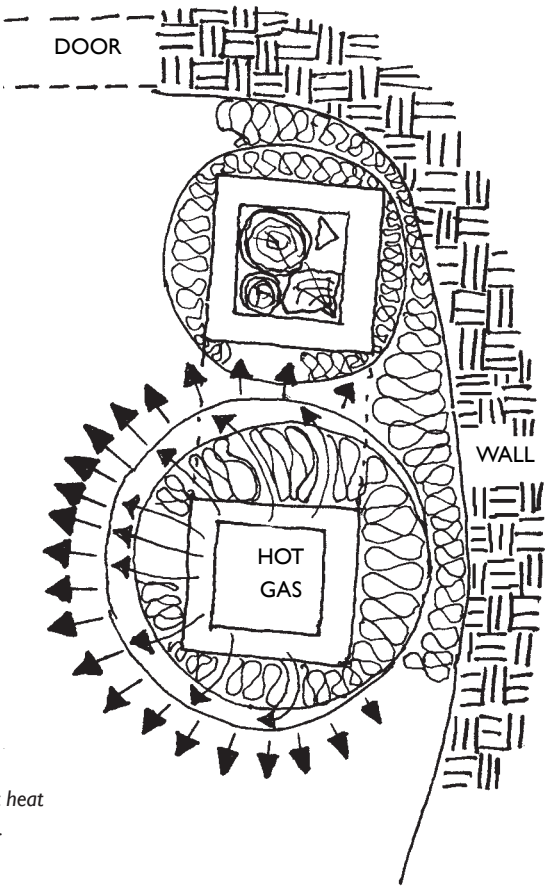
In very cold areas, you may want to reduce uncomfortable drafts by bringing in outdoor air above the Feed Tube, either by a 4- to 6-inch pipe through an outside wall or through an attic space and down through the ceiling. In mild climates, say USDA Zone 6 or higher, this may not be advantageous. ***Don't build directly on a wooden floor or up against a wooden wall.*** (See directions on page 76 for building on a wooden floor.) Be sure not to place Heat Exchange Barrel or Feed Tube beneath anything in the room that may present a fire hazard, such as overhead shelves. Be super-cautious about any materials such as framing, paneling, or furniture nearby. Exposure to high temperatures over time lowers the flash point of that material.

Several variables change where the heat is delivered. You can divide the mode of heating (radiant, conductive, or convective) your stove supplies according to your needs. There is a trade-off between fast radiant heat and a long-lasting Thermal Battery. What heats up quickly—for example, a radiant barrel with little insulation around it—also cools down quickly. Conversely, what heats up slowly cools down slowly, so a system with its pipe sunk several inches into a massive bed or couch provides warm comfort all night and into the next day, hours after the fire has gone out. Decide well in advance of building how you'd like heat delivered by your stove. Want to warm up fast? Cook? Or cozy-up on a bench for hours with your book or cat?



Eccentric gap around Heat Riser/insulation to favor radiant heat into the room. Serious insulation against exterior wall.

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For instance, to maximize cooking efficiency, keep the top of the Heat Riser close to the barrel, about 2 inches away, and keep the Burn Tunnel short. You will create a circular hot spot in the middle of the barrel top. For the most usable radiant heat, leave a wider gap inside the barrel on the side where you would be sitting, and tighten the sleeve on the other sides—especially against a wall or window. For a quick warm-up in the room, you could build a taller Heat Riser with a bigger radiant barrel, possibly welding two barrels together end-to-end or using another conveniently sized metal container. Colleagues have used a taller narrower container from an old electric water heater.

If radiant heat is prevented from escaping from the barrel, more heat flows into storage. Part or all of the barrel can be encased in cob, and/or the barrel could be replaced by brickwork making a bigger proportion of your heat available for storage and contact warming. You may want to size storage and the length of buried flue with that in mind.

If the wall behind the stove and bench is not well insulated, insulate the side of the stove facing the wall with 2–4 inches of clay-vermiculite, clay-perlite, or even clay-sawdust. Building codes demand 18 inches of space between stove and wall.

The Thermal Battery

Working with cob* offers structural flexibility like nothing else. Cob is a structurally bonded mix of clay soil, sand, straw, and water, smeared together to a cohesive consistency and applied by hand. This medium is eminently sculptable because you apply it handful by handful. The shapes are as limitless as anything you can build with clay, though you should avoid sharp corners, which can break off easily.

To build your Thermal Battery, use rocks or urbanite (recycled concrete chunks), filling the gaps with no-straw cob. If space is tight, use as much rock as you can, because rock stores more heat than clay. The easiest way to make small quantities of cob is to lay a tarp on the ground, dump the ingredients on it, then roll and tread the mixture together with your bare feet. The final consistency for heat storage should be very sandy and homogeneous, just sticky and damp enough to hold together for hand-sculpting. (For a thorough explanation of cob, see *The Hand-Sculpted House* in Recommended Books.)

The shape you end up making your heat storage can be elegant and eloquent, whimsical yet grounded and comfortable, in conformation with your body's geometry.

The Thermal Battery works by slowly absorbing heat while there's a fire burning. That heat disperses throughout the mass and finally leaves slowly, mostly by contact and convection, mostly in zones where you want it to leave. Total heat storage is limited by weight, not volume, so use heavy materials packed tight around the heat-transfer ducts, then lighter, better-insulated materials to enclose the whole thing, to delay cooling.

Different materials conduct at different rates. Gravel packed tightly conducts more slowly than solid rock. A loose stack of urbanite conducts less well than a tightly packed one or the same volume of tightly packed gravel, because the pieces need to be in good contact with each other. In rural areas, it's worth making your own conductive mass with rocks, sand, gravel, and a binder such as Lasse Holmes's claycrete (see case study, page 100).

* See Glossary

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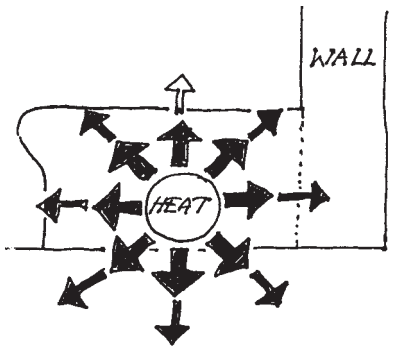
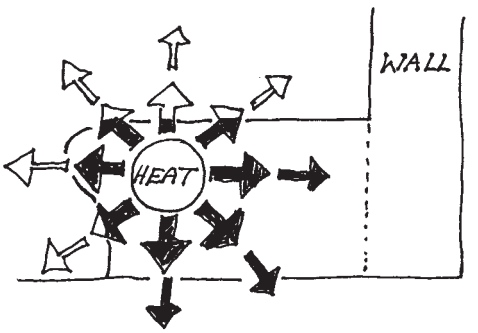
Placing the Pipe

The longer the run of duct inside your bench, the more heat you can extract from the combustion gases. For more even distribution of heat across a wide bed or floor, you can loop the ducts back and forth or run more than one from a common feed, reuniting them later. Bench systems with 30 feet of pipe work well and can reduce the exit temperature of the gas below 100˚F, thus storing a very high proportion of the heat generated. For example, the 8-inch pipe in one of Ianto's benches is 31 feet long. When it's burning really hot, Ianto can actually lick the metal exhaust pipe, to the amazement of visitors.

Heat travels through cob at about 1 inch per hour and through rock about twice that fast.



Exhaust tube sunk low in the center of the bench allows more heat storage in the bench and in the floor beneath it.



With the exhaust tube located higher, the surface of the bench heats faster, but less heat is stored and the bench cools faster.

You can retain most of the heat generated with 26–30 feet of 8-inch duct, surrounded by 1–3 tons of heat storage mass. Generally, it is advisable to set the ductwork fairly low in the bench. This gives more even heating and retain heat a lot longer, especially as ash accumulates at the bottom. Ash is a good insulator, so less heat travels downward than upward or to the sides, unless the duct is always scrupulously clean. On a masonry slab floor (concrete, stone, cob, adobe, etc.), you can make use of the thermal mass of that floor by positioning the ducting deep, down close to floor level. This delays heat delivery to the surface of the storage mass but stores a lot more heat for a much longer time. On a wooden or suspended floor, however, structural and fire concerns prevent using the floor for heat storage. (See page 67 for details.)

The duct that carries the hot gases through the bench can be positioned high to deliver fairly fast heat, but at higher temperatures. For instance, a duct with 2 inches of cob above it would provide a hot strip about 2 hours after the stove is lit.

A duct that is too close to the surface can make the bench uncomfortably hot along a line above the duct, yet quite chilly to either side. Ianto's first Rocket Mass Heater had a 6-inch duct only 2–3 inches below the surface. To store sufficient heat to warm the building adequately in very cold weather, he once got the bench so hot that it set fire to the cotton padding in the futon on top of it. If you plan to have a thick mattress or cushions on top of the heated bench, keep hot ducts deep in the body of the bench—6 inches, if possible, but allow about 6 hours for heat to arrive.

There's no necessity for the duct to continuously rise toward the exit. In fact, if you want to create a hot spot in the bench for rapid warm up, you can bring the pipe up close to the surface, then drop it again.

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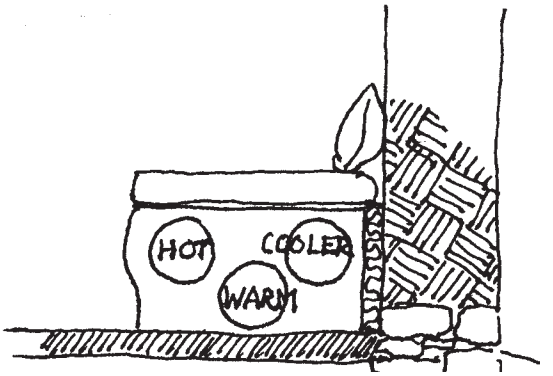
Sizing Built-In Furniture

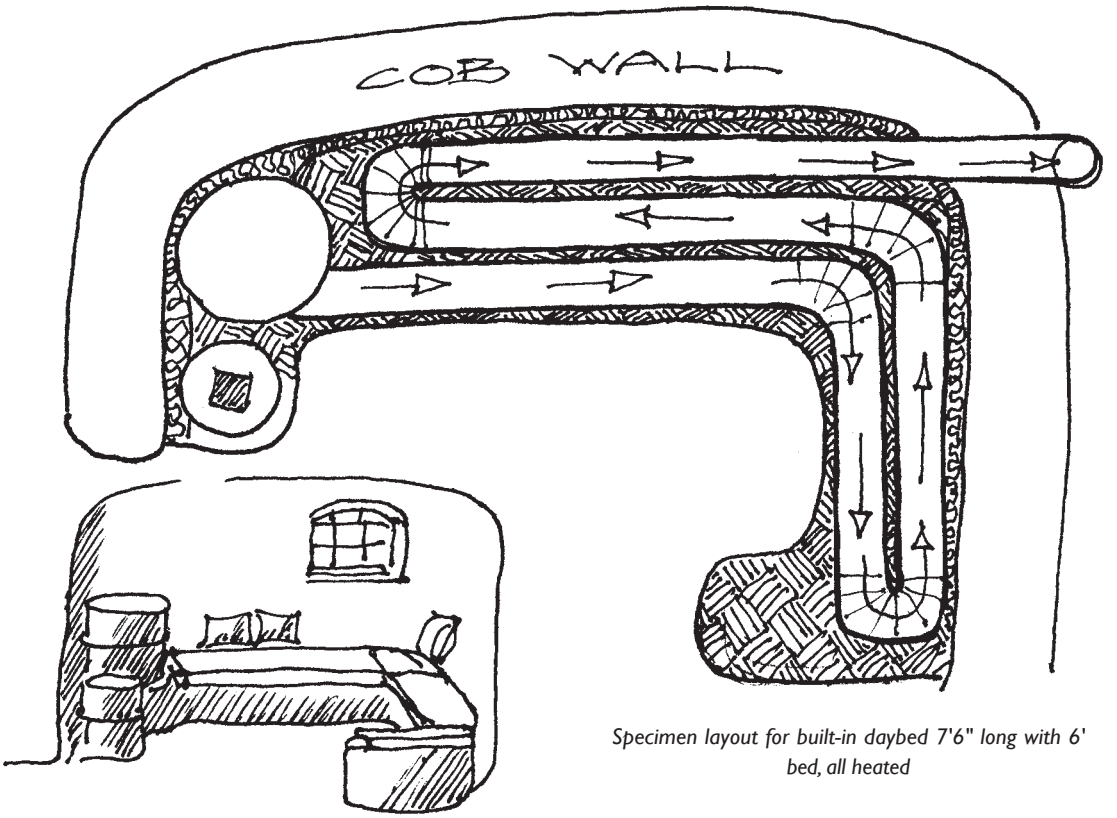
Wall benches are comfy at 18 inches deep (front-to-back), though tolerable at 15 inches. They should be 14–18 inches high. A lower or narrower bench has less capacity to store heat. The bench is most comfortable if it is narrowest at feet level, being undercut 3 to 5 inches, so there is space for your heels when you are sitting down. Make allowance for the overhang when you begin building.

If against a wall, a heated bed should be at least 7 feet long, with the width 2½ feet (single) or 4½ feet (double). If free-standing, it should be wider. You could accomplish both heated bench and bed by designing a bed that tapers at the foot and is widest at the shoulders. When sizing bench or bed height, allow for mattress or cushion depth, so unless you're certain there will never be cushions, keep it lower—in the range of 14–16 inches.

At 7 by 4½ by 1½ feet high, a cob bed would weigh about 2½ tons. A 1½-foot-wide bench 15 inches high would need to be 10–12 feet long to weigh 1 ton. In either case, a deep-set exhaust duct on top of a mass floor could substantially increase the effective amount of heat stored.

Against an outside wall, you'll lose heat through that wall. Loss can be minimized by built-in insulation between wall and bench: 3 inches of clay-sawdust or clay-perlite-vermiculite in cold climates 2 inches otherwise.





Specimen layout for built-in daybed 7'6" long with 6' bed, all heated

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PLANNING THE EXIT FLUE

Positive Pressure and Toxic Gases

Chimneys for Rocket Mass Heaters behave differently from those of most woodstoves and thus have different needs. Remember that burning wood creates water vapor even if the wood is bone-dry. But gas temperatures are so low at the exit of Rocket Mass Heaters that fire danger is almost zero, but because of these low temperatures when it's cold outside, water vapor in an exit stack is likely to condense, with creosote in solution sometimes. Higher efficiency of combustion and more efficient use of heat produced means a generally lower output of gases, so the slower passage of cool moist gases contributes even more to condensation. Some things to consider:

Less fire danger.

Low exit temperatures allow more creative stack placement (e.g. under the eave, though don't relax fire precautions with less than 15 feet of horizontal pipe or an exit gas temperature above 150°F).

More condensation.

Even if fuel is bone-dry, burning wood creates a lot of water vapor. In a regular box stove, that vapor is normally swept at high temperatures up the stack. But in a Rocket Mass Heater, that gas lingers and cools while it charges the bench. Rocket Mass Heaters burn less wood, thus generate less gas. That gas moves slowly and the cooler stack encourages condensation. The pipe exiting through the wall of the house should drop slightly to the outdoors, with a ½" hole drilled at the lowest point. This allows any condensation in the vertical pipe to drip out. Use stainless steel for a more durable stack, but check that the rivets are also stainless, or the pipe junctions may pop apart when the rivets rust.

Toxic gases.

Because condensate is acidic, unprotected steel corrodes very quickly if it is uninsulated or exposed to rain, or if its inside surface is not galvanized.

Consider carefully where the exhaust pipe will exit the building and where its outdoor end will be. Because a Rocket Stove pushes gas along the Exhaust Flue, there is slight pressure inside the flue trying to squeeze gas out through any cracks. At some point of the burn, CO and nitrogen oxide (NO_x) are present, both very toxic. So, if you leave any metal pipe exposed inside the building, seal the joints very thoroughly with high-temperature silicone or high-temperature tape, to make really sure no gas can escape. With clip-together stovepipe, seal all along the clip joint as well as the connections between pipes. Then test for leakage by building a very smoky fire and blocking the exit at the top of the flue.

Make particularly sure the cleanouts and primer hole are well sealed. Any small crack downstream of the Heat Exchange Barrel could leak dangerous gases, especially if the flue is long and/or you have an exposed pipe. It's worth investing in a CO detector. They are inexpensive and easy to find. In cold climates, an exterior stack will harbor cold air, which falls into the building. Try to avoid tall exterior stacks, or start your fire with really flammable paper/kindling to push the stack clear of cold air.

Wind.

The volume and speed of exit gases from a Rocket Mass Heater is often less than from a box stove, even less than from a fireplace, so gusty conditions outside or simply a steady wind against the end of the exit pipe can force exit gases back down the flue. Running the Exit Flue up above the roof ridge will probably deal with wind problems and with the fire department, but it is a costly solution. It's hard to predict where this may be a problem, so have an alternative plan if there's even a suggestion of smoke backing up into the house. If there is a known prevailing wind at times when you'll be using your stove, try not to exit your stovepipe on that side of your house.

Consider relocating the pipe completely on the downwind side of the house, or making it much taller, or using a commercial wind cowl on the top. Chris and Jenn Reinhart used the commercially bought Vacu-Stack (lowest illustration, following page). It is a stovepipe cap that creates suction as high winds blow into it, so it actually draws more in the wind instead of allowing the gases to be blown back into the house. For Chris and

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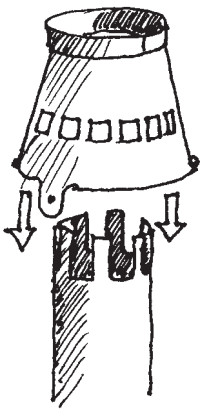
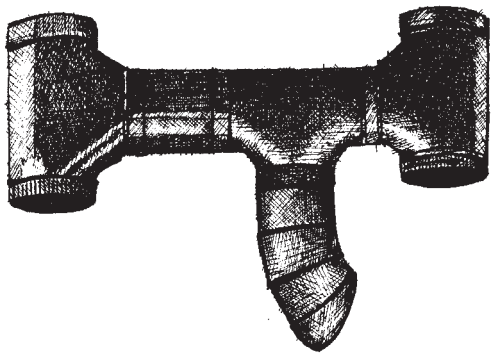
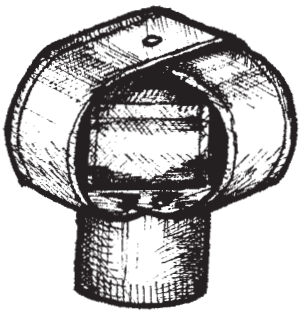
Ernie Wisner has used a galvanized steel bucket set over the end of the flue, with slots cut into the pipe for gas to escape and holes in the side of the bucket. Sometimes it helps to constrict the top end of the chimney flue, as do European chimney pots.



Preventing blowback



Chris Reinhart. Solutions: #1. D.I.Y. Three Ts and a coupler prevent wind from blowing down the flue.



#2. Commercial product: arrangement of baffles creates "suck" as wind blows through.

Jenn, "It works great, but to the tune of over $150. This is what we are currently using, with plans to implement the 'old-timer's' way of doing things, which is three stovepipe Ts attached together so that wind blowing in is more likely to keep blowing out rather than turn two corners to go down the pipe into the house."

To stop rain accumulating in the stack, mount an elbow on the top of the pipe and point it slightly downward. A piece of ¼" hardware cloth over the end of the flue will prevent animals climbing in.

Some things to consider about chimneys:

As a city slicker, Leslie has envisioned exiting the flue pipe low, like a clothes-dryer vent. And the stove at Ianto's exits just under a low eave of the slopy-roofed cob building low and clean enough that Ianto could lick it (to the shock and delight of guests). But many stovers have come back to us about more common roof situations than the single-storey sloped roof of a cob cottage.

Q. Should I exit my exhaust pipe down low?
A. Kirk Mobert has this suggestion: "If there are pressure issues anywhere, a taller chimney solves them, as long as there is heat to drive it. The side-port out only works in situations where there is very little wind."

Q. Should I keep the stack inside as long as possible to strip a little more heat from it?
A. By the time the Exit Flue is leaving the bench, it is not giving a significant amount of heat to the building, however, there are good reasons to keep the Exit Flue inside the building as long as possible not so much to benefit the room's warmth, but to benefit the pipe's draw. A warmer Exit Flue will also help you start the fire.

Q. Should I go all out and build a masonry chimney or just settle for metal pipe?
A. Be careful! Masonry chimneys don't work well for Rocket Mass Heaters. In cold weather, they can cool off and cause downward convection of cold air, pushing against the pressure created by your Rocket Mass Heater. Additionally, they take a lot of materials and labor; they are a potential entry

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point for rainwater, and in earthquakes, they are often the only things to fall down. Our preference is for a high-quality metal pipe, though it may not be as durable.

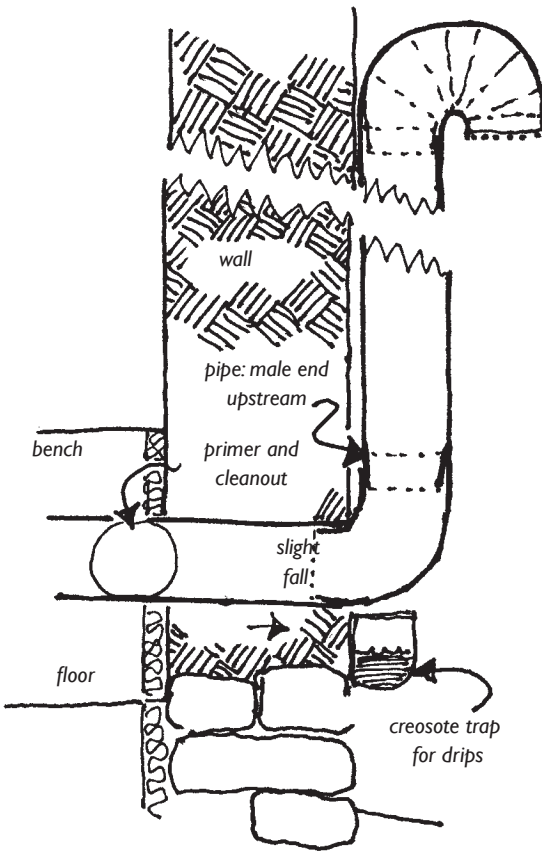
Q. Should I put a chimney damper in the stack?
A. NO. Never install a chimney damper! It can cause CO to back up into the room.

Q. I want to insulate my exterior stack to help with the draw. Should I purchase an insulated stack?
A. Avoid Metalbestos. It is loose-filled with toxic industrial slag waste that settles over time, rendering it ineffective—and dangerously so, as creosote can form in the settled areas and cause a (toxic) chimney fire. Look for insulated pipes (such as Excel and DuraVent) filled with mineral wool fiber that doesn't settle.

Q. Can I vent a Rocket Stove into an existing fireplace or chimney?
A. [*Contributed by Bernhard Masterson.*] For newer homes that have double-wall insulated pipes for chimneys, venting an RMH into the existing chimney should work well.

For a masonry chimney outdoors the greatest challenge can be temperature inside the chimney. Cold brick creates dense heavy air, and the warmer flue gases are not usually hot enough to push their way through what is effectively a plug of cold air. This can usually be solved by lining the chimney with a pipe of the same cross-sectional area as the bench ducting. Providing insulation to that chimney lining helps further. Because flue temperatures are low, insulated flue pipe isn't necessary to protect the masonry chimney but could be used to keep the flue gases warm, thereby improving the stove venting and draw. Commercial insulated pipe is expensive and unnecessary. You can pour loose insulation (perlite, vermiculite, lightweight pumice) into the space around the pipe.

Masonry chimneys inside homes should be warmer because they are heated to some degree by the house. As a result they may not need lining for an adequate draw. Whether or not you need to line the chimney has much to do with the size of the chimney, and whether it is lined. If it is lined with flue tile, the dense cool air from outside will still puddle in the bottom of the chimney. A good draw on the Rocket Stove may not be established until the mass of the chimney has been warmed. If you are permitting your RMH you will likely be required to line the chimney with metal pipe to meet building code.



Make sure the flue tilts down toward the outdoors, male ends of pipes are upstream (not necessarily up the pipe vertically), and there's a primer just inside the building.

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Materials & Tools You'll Need

for an 8-inch flue system with a cob bench for heat storage

MATERIALS

Bricks, about 60–70 for the entire combustion chamber; if you don't use brick for the Heat Riser, 30–40 should do it, some can be damaged/partial
Clay or clay soil
Mason's sand } for cob and cob mortar
Straw (½ bale) or dead dry grass
15–17 gallon barrel for the Feed Tube (optional)
55-gallon barrel for the heat exchanger
8"-diameter stovepipe/metal duct (enough to run all the way through the heat storage and provide your Exit Flue)
Insulation: vermiculite, perlite, or lightweight pumice (a 4-cubic-foot bag is plenty)
Insulation container: water heater tank, ⅛" wire mesh (metal screen), metal roofing, or sheet metal (big enough to contain all the insulation)
Urbanite*, rock, or brick, and gravel for heat storage

Alternative Heat Riser: 8" insulated double or triple stainless steel pipe or 8" solid steel pipe at least ⅛" thick, height of Heat Riser

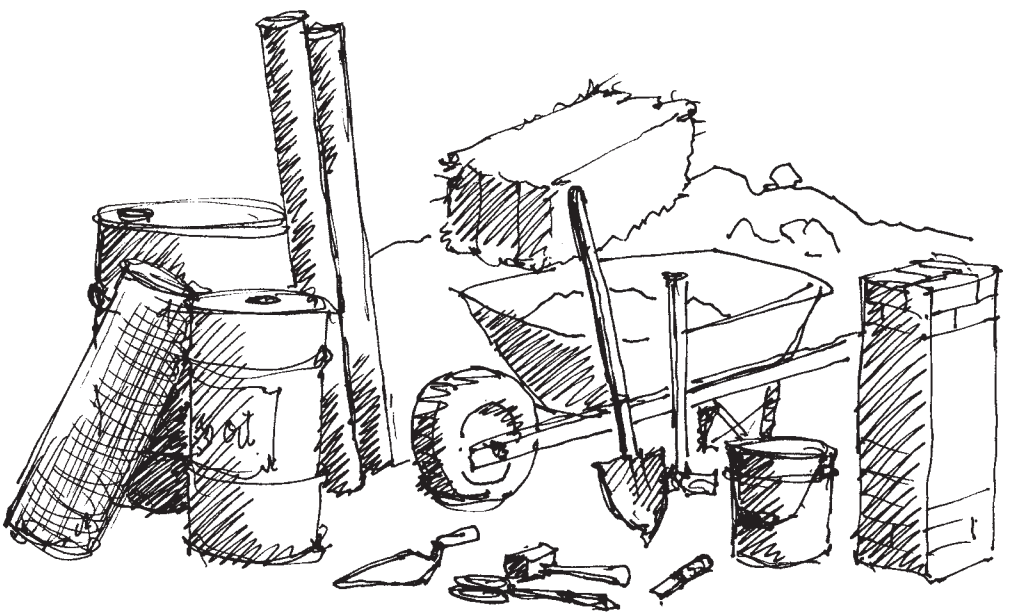
TOOLS
that are essential

Shovel
Machete
Mattock or pick for excavation
Buckets, several
Wheelbarrow/handcart
Sharp pocketknife
Builder's level, 4 feet long
Measuring tape

OTHER TOOLS
that you might need

Plastic tarp, about 8 x 10 feet
Hammer, cold chisel
Brick hammer, brick chisel
Safety goggles
Mason's trowel
Probe-type chimney thermometer
Tin snips, pliers
Old window screen (for sifting sand)
Rags

**See Glossary*



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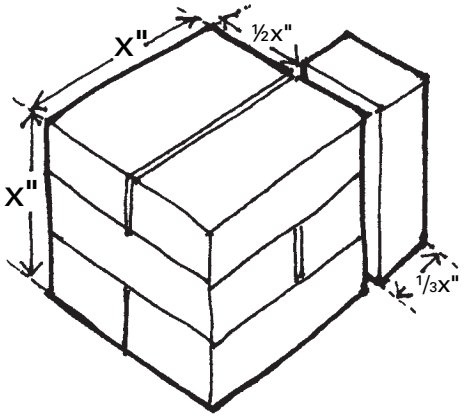

Most bricks have proportional dimensions, firebrick notably so.

BRICKS

From the bottom of the Feed Tube to the top of the Heat Riser, temperatures are intense. Temperature can rise very fast, so the materials need to withstand sudden thermal shock and of course not melt or burn at up to 2000°F. We have tried a lot of different materials and in general find the most durable to be soft common brick. Sooner or later some bricks seem to crack or crumble in the extremely stressful conditions inside the area of combustion. The first brick of the bridge over the Burn Tunnel is particularly vulnerable, so design your stove for easy replacement of this sacrificial piece. Low-density firebrick/kiln brick is a really good insulant, though very expensive and frail. It could make a good Heat Riser. Soft common brick seems to work well, is easy to cut, and is often more resistant to cracking, particularly really old, low fired orange colored soft brick. But old bricks can be of irregular size and shape, so make sure you have matching dimensions for each course.

You need sufficient bricks in good enough condition to do the job. Most of them need to be intact or at least with defects limited to the least critical places, though you may be able to use some partial bricks. Bricks should be clean of mortar, without bulges or large parts missing, and quite similar in size. Clean off lime mortar by rubbing two together, grinding every face flat, or use a machete, flat blade, or brick hammer first. Note that many bricks are made to modular proportions to fit together in all dimensions. Thickness is about a third of length, width about a half, allowing for mortar joints. Old bricks were not necessarily made to standard dimensions and different manufacturers each had their own size. Any irregularities should be readily apparent. (See sorting bricks diagram, page 46). The more irregular your bricks, the more mortar it takes to keep them *evenly spaced or apart* as you build. You'd like to limit mortar thickness because brick is stronger than mortar and you want to minimize the weakness inherent to mortar joints.

CLAY

Clay soil can be found in the ground within about a mile of most places in North America and is a waste product of most building sites on clay soils, or can be found where farmers are draining land, or sometimes in sand/gravel quarries or graveyards. It will probably be mixed with sand, silt, organic matter and possibly stones. For making mortar, you will need wet clay, pressed through a $^{1}/_{16}$" screen or a metal fly screen, to remove rocks and impurities. For the Combustion Unit (that is, the stove itself), you need no more than 5 gallons.

If you can't find native clay, you could buy potter's clay from a ceramic supply store or ask your local potter for unwanted scraps. Or buy a bag of powdered "fire clay" from the building supply store; it performs well at high temperature and is easy to mix for mortar.

For building the cob parts of the heat storage (such as a built-in seat or bed), the soil may not need to be screened. If your clay soil is rich and sticky, you need up to a half-ton or so (about 15–20 five-gallon buckets) to build a heat storage bench or bed. If the soil has less clay, you need more of it, but it needs less sand to stabilize it against cracking.

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SAND

For mortar, you need a bucket full of 1/16" screened washed **mason's sand**, which you can either buy from a building supply store or screen yourself from cheaper coarser mixed sand. Don't use fine sand from beaches or sand dunes; it doesn't lock together well. Additionally, if you are building the heat storage with clay-rich soil, you need **builder's sand**, sometimes called **concrete sand** or **fill sand**—quite a lot, depending on the size of the storage unit. It is normally sold by the cubic yard and you can expect a cubic yard to weigh over a ton, so don't put more than half a yard in a half-ton pick-up truck. Start with half a yard and see if that's sufficient. You can always get more later.

BARRELS

To contain the hot gases issuing from the top of the Heat Riser, we often use a simple steel barrel, though people have used water heater tanks, garbage cans, or custom-built cob or brick cylinders. You can regulate the amount of heat that the barrel gives out by the size of container you choose, and by whether parts of it are surrounded by a thermal buffer of cob, brick, etc. As you design your system, remember that it's the *interior* height of the barrel that is important.

If you wish to contain the fuel that sticks up above the Feed Tube, those 15- to 18-gallon grease drums that you sometimes see in bulk food stores, gas stations, or truck repair shops are ideal. Some have a press-down lid with rounded tabs all the way around the edge. Take out the rubber gasket. Usually, there's a 2-inch hole in the center with a threaded cap that you can screw in or take out. Rocket Mass Heaters with an 8-inch flue won't get quite enough oxygen to sustain a clean burn with the lid on snugly and the bung open, but leave the lid loose, or you can gradually ream the bung out with tin snips, experimenting with your test model as you increase its size until you find the sweet spot.

Used barrels are available many places. You shouldn't have to pay more than about $20 for a really high-quality 55-gallon barrel, less for one smaller. It might be worth trying one with a detachable clamp-on lid for ease of inspection, cleaning, etc. Try your local dump, bulk food stores, or caterers, building materials reuse stores, secondhand stores, scrap metal places, and old industrial sites. Other sources include yard sales (ask, because they won't have them up front with the clothes and books), suppliers of honey or cooking oils, service stations, and mechanics. Fifty-five-gallon barrels are easy to find, but in some areas smaller ones are scarce, as plastics take over the barrel industry.

Barrels, in this case two 55-gallons, a 25, and a 17, often unwanted and in good shape.

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Barrels are highly likely to be painted and may have residues of what they contained. It's necessary to remove the paint before you get them inside the building. You can do an adequate job with industrial sandpaper or an angle grinder or a good hot bonfire. Clean out as much residue as you can before you burn them, and make sure the bungs are detached before they get near the fire. Stay upwind and wear a respirator, as the paint on a barrel (not to mention the mysterious substance on the inside) can be toxic. Think about who is downwind. After burning, use very coarse sandpaper from an industrial sanding belt to take off any remaining paint. You can use it with or without the belt sander.

STOVEPIPE

You need pipe to form the tunnels in your heat storage, or you could build a brick or adobe tunnel. The tunnel, however, does need to have a smooth interior surface so the gases can flow along it gracefully without being slowed by the drag of the walls. So the best option is to build your bench, bed, etc. over metal ductwork or stovepipe.

Pipe diameters should be the same through-out. (Referred to as "system size" or cross-sectional area [CSA].) Measure the diameter in advance: occasionally you will find a piece of 7½" in the 8" pile, for instance, and they won't quite fit together. You need a tight fit to prevent CO escaping through cracks in your masonry. It's helpful to have adjustable elbow sections of the same diameter for changes of direction.

Buying new stovepipe can be expensive. Used pipe is relatively cheap. Go to your local building reuse place, or a rural dump, or try yard sales, secondhand stores, or dumpsters where demolition is happening. The pipe doesn't have to be in perfect condition—even small holes, dents, etc. are okay. Seal cracks, joints, and holes with high-temperature tape. Reuse stores in some places are not allowed to sell certain used stovepipe, so we have been asking stove contractors and dealers to save us their used pipe, which would otherwise be thrown away.

Preferably the pipe should be circular in section, not square. For strength, use steel, not aluminum. You're going to leave it inside the furniture, so it's best if it's not painted, as some paints off-gas at bench temperatures and could seep through cracks in the cob or masonry.

HIGH-TEMPERATURE INSULATION

Thermal insulation uses trapped air to prevent the passage of heat. The more air in a substance, the better it insulates: witness your down-filled parka or thermal sleeping bag. Thus the insulation you use should be as light as possible. We have found three loose-fill materials that work well to insulate the Heat Riser in a Rocket Stove: lightweight pumice, vermiculite, or perlite, all to be mixed with clay slip. All three are fairly easy to find, inexpensive, and simple to use. Both vermiculite and perlite may give off dust, so use a respirator when mixing them. Buy the coarsest grade of perlite you can find. It's available in big plastic bags at building supply stores and nurseries.

Make a clay slip by mixing clay and water very thoroughly. You can do this in a bucket with your bare hands, with a paint paddle on an electric drill, or with a wooden paddle. We like the bare hands method; it's nice to feel the clay between the fingers. The clay slip helps to bond the lightweight dusty particles together and to hold a shape. The mixture should be about the consistency of paste, thick enough that after you dip your hand in it you cannot see your skin.

Mix 1 measure of slip to 6–9 parts of insulant. Dump a few gallons of insulant onto a tarp or into a wheelbarrow and sprinkle the clay slip over the pile as broadly as you can. Tumble the pile with your bare hands or a shovel or by rolling the tarp. Try different methods. The idea is to get the white grains dirty all over, totally clothed in clay. It may take quite a lot of time to mix completely. When you're through, you should be able to compress together a little snowball of the mixture and have it stay intact. Don't use any more clay than you have to, because clay is denser than most insulants and reduces the insulating qualities of the mix. And don't compact the mix while tumbling it or setting it into the stove. Compaction reduces the insulative value.

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Most fireproof insulation is in the form of either loose-fill or sheets of fiber such as kiln insulation or spun kaolin. Both need to be contained, even if you mix clay with loose-fill. Create a cylinder of wire mesh or sheet metal, or perhaps use a ready-made container such as an old water heater tank with the ends cut off. Used materials should be quite adequate, obtainable from scrap metal merchants, your local dump, or used building materials centers.

For load-bearing high-temp areas such as underneath the Combustion Unit, Lasse Holmes likes a commercially produced sheet product called Foamglas. Typically available in 2-inch rigid sheets, it is free of flame retardants, moisture resistant, and made from recycled waste glass.

STEEL PIPE

If you choose to use a pipe for the Heat Riser, the best source is usually a scrap metal place. Sometimes they will cut it to length. It should be at least ⅛" and preferably ¼" thick. Pipe can be round or square, but note that a square tube of the same cross-sectional area won't carry gas quite as fast, so for an 8" round flue you might use an 8" square Heat Riser. If you choose steel for the Feed Tube, Burn Tunnel, or Heat Riser, be aware that upstream—where oxygen is plentiful—it will eventually burn away.

Donkey boldly says, "If you have a Rocket Stove that operates the way it should, it will chew through metal (any gauge, mild or carbon) very quickly. Anyone who says otherwise is either using rather expensive heavy-grade stainless steel or has built a crappy stove. Period."

For the Heat Riser, several people have experimented with used triple-wall stainless steel pipe. Its durability in Rocket Stoves is not known, but its thermal mass is low and its insulation value is high. So it could be valuable and your stove will heat up faster. It makes narrower Heat Exchange Barrels possible. In some areas triple-wall is available secondhand. (Since early editions, we have used it repeatedly.)

Hot gases spiral up a flue. A round flue carries more gas, more smoothly.

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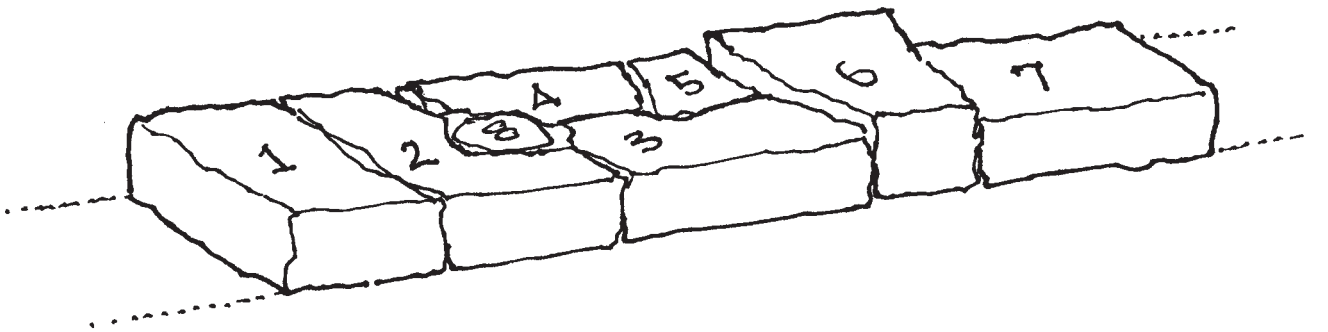

Selecting urbanite. Choices in order of preference are: (1) Parallel sides, right angle corners, good face on each side of wall, rectangular. (2) Two good faces, three right angles, large. (3) One long good face. Half-width of wall, large. (4) Long face, half-width of wall. (5) Small, half-width of wall. (6) Less desirable: two good faces, but stone is thicker or thinner than most (problems laying next course). (7) Big and one good face, three right angles, but being about ¾ wall thickness, difficult to add to alongside. (8) No good faces, but can be used as infill.

URBANITE

Urbanite is a common "mineral" found mostly in cities. When sidewalks, driveways, patios, and garden paths are broken up, chunks of concrete are often hauled off to a landfill dump or recycled to make gravel. Urbanite is very common in the waste stream and sometimes can be delivered free to your site or is at least free for the taking, saving the owner a dump fee. Urbanite is very heavy, so the economics of hauling long distance soon get to be an issue. Look for it close to your building site. Go with a sledgehammer and goggles, as you may need to break it up at the source. A wide 2-inch-thick board about 8 feet long makes it easy to slide heavy pieces into your vehicle. Look for chunks 3", 4", or 5" thick. Avoid pieces with rebar or wire mesh reinforcement, as they're too hard to break. For ease of layout, try to choose pieces that are the width of your bench or about half that width, nothing in between. Ideally they will have sides that are parallel and some right-angle corners. The biggest pieces you can handle (with one or two people) are most useful.

STRAW

Straw is the fiber portion that gives cob its tensile strength. Use it in the outer coats of cob, to hold the whole mass heater together. Be sure to get *straw*, not hay. There are many sources, including animal feed supplies, castoffs from carnivals or county fairs, and large strawbale house building contractors who have purchased extra. Used horse bedding, although it may contain urine or dung, makes excellent cob. Just make sure the straw bales haven't gotten wet, as the inside straw can invisibly rot and cause problems.

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Step-by-Step Construction

For first-time builders, we describe a single well-tested model that we know works well and is easy to build. It's what we call an 8-inch model, in that the cross-sectional area of each tube is equivalent to an 8-inch diameter tube, that is, about 50 square inches. Here is a suggested order for designing and building the stove and its attached heat storage.

1. Inspect the site where the Rocket Mass Heater will be built.
2. Measure the space available. Take notes. Make a plan or drawing.
3. Design your stove and heat storage unit to fit the available space.
4. Do a scale drawing of brick layout (use ¼" graph paper).
5. Assemble tools and materials (see list, page 39).
6. Clean all bricks, remove paint from barrels, make sure all pipes fit together, straighten them if necessary.
7. Outdoors, build a mortarless mock-up of the combustion chamber (use the materials for the permanent stove).
8. Experiment with fire in the test model to troubleshoot and optimize your system.
9. Level and compact the stove site, if needed.
10. Roughly draw out the position of the base of the entire device, including ducts, etc. Adjust as necessary *in situ*.
11. Re-check the design. Does it still make sense?
12. Mix mortar, then cob, then insulation.
13. Install any insulation needed below the stove.
14. Build the combustion chamber including the Heat Riser, one full course of bricks at a time. Check level and plumb at each course.
15. Set up containment for insulation around the Heat Riser.
16. Pack insulation in.
17. Install a big barrel around the Heat Riser, adjusting the height for optimal burn.
18. Test combustion again. Adjust the barrel position if you want more heat from one side.
29. Connect all the parts of the internal ductwork.
20. Open all the windows and test drive.
21. Build the heat storage mass.
22. Test-drive again.
23. Clean up.
24. Fire up the stove, put on tea.
25. Heat up the house and invite all the neighbors to the feast.

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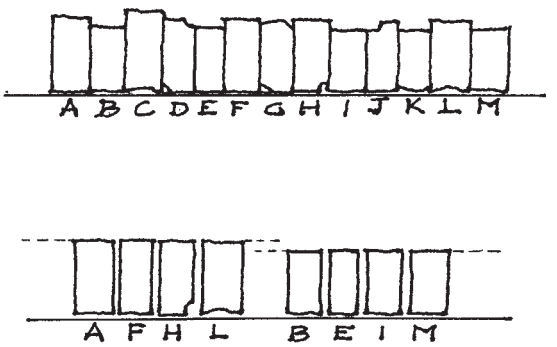
A MOCK-UP

Begin by laying out your bricks on any unburnable flat level surface, preferably outdoors, to practice how they might go together. We recommend you build a mock-up—without mortar—of the entire brick structure, not necessarily in the final position, and fire it up really hot to make sure it works.

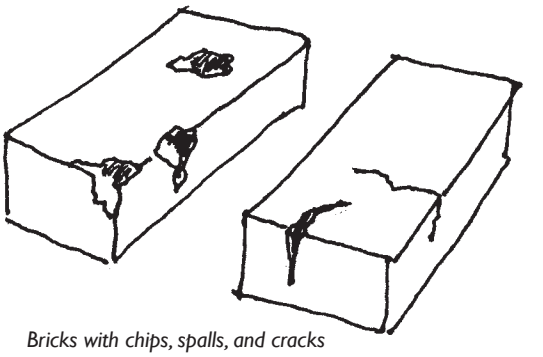
For the Feed Tube and the Heat Riser, use bricks on edge to keep the tower as thin as possible so it doesn't take forever soaking up heat, and to leave plenty of space for insulation. In the base and along the Burn Tunnel, bricks can be laid flat and/or on edge in various combinations to get the interior height of the Burn Tunnel right.

It helps to use bricks exactly the same height within each course (not a concern if you have new, perfectly identical bricks). Easier than measuring them and more precise is to lay them out on a really flat surface such as a straight board or a level flat floor, a dozen or so at a time.



Sorting bricks: A, F, H, and L are all the same height. B, E, I, and M are a different height but are equal to each other. Each group of four makes a course of the Heat Riser.

Sometimes instead of using bricks we build the Heat Riser with *thick* steel pipe (⅛" or ¼") and recently, people have used triple-wall insulated stainless steel.



Bricks with chips, spalls, and cracks

INSULATION UNDER THE STOVE

When you design your stove, decide how high in the room you want it to stand. Then calculate the height of the floor of the Burn Tunnel. It can be at, below, or above the floor level of the room. You may want to plan for a few inches of insulation below the Burn Tunnel. The insulation (**e** in the cross-sectional drawing on page 28) and the brick ash pit (at **g**) could be inset into the floor or laid on top. (Recessing stove parts into the floor is a lot easier if you build stove before floor.) The floor of the Burn Tunnel should be level, flat, solid, and at least 2 feet in any direction from any burnable parts of the building. ***Don't build directly onto a wooden floor or up against a wooden wall.*** (See directions on page 67 for building on a wooden floor.) Be sure not to place the barrel or Feed Tube beneath anything such as overhead shelves that may present a fire hazard.

Build the permanent model on a hard flat level base, preferably brick. Smooth common brick works well. Whether to use insulation beneath and around the Burn Tunnel depends upon whether you want to use the ground beneath the stove as thermal storage or are more interested in having your stove heat up quickly. If, for instance, a main function of your stove is to heat your morning coffee, then you want to keep the gases hot through the system, losing as little heat along the way as possible.

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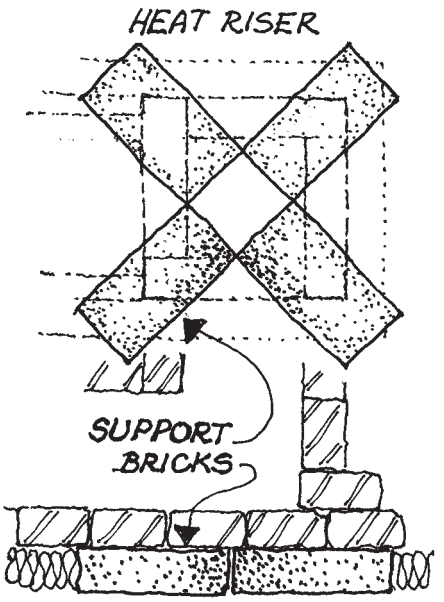
On the other hand, if the stove is to be used only for space heating, charging up a heat storage bench, or even slow cooking, then it might be in your interests to allow the ground beneath your floor to heat and slowly release that heat over time.

Bernhard Masterson suggests a diagonal cross-support of bricks laid flat in the insulation beneath the Heat Riser to support the weight without crushing the insulation.

MORTAR

You can either mix your own mortar or buy commercial fireplace mortar. To make your own, you need mason's sand (fine-grained sharp sand) and fairly pure clay. Unless you buy commercial clay, put both of them through a 1/16" screen or a fly screen, to eliminate hard lumps on which the bricks could teeter. Don't use cement-based mortar unless it's fire cement mixed with clay. Most cement is nonrefractory and likely to break up rapidly from thermal shock. The same may be true of lime, whereas clay merely becomes fired and in fact turns into a brick-like material.



Infloor insulation: shows diagonal brick support for the weight of the Heat Riser (above in plan view), surrounded by mineral insulant (below, in section view.

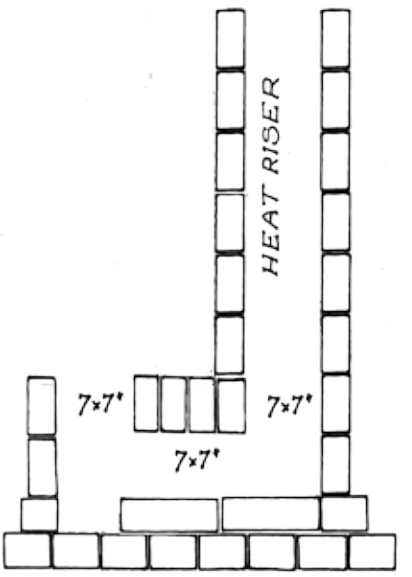
Mix in advance about half a bucket full of mortar, that is, 2–3 gallons, at about 1 part clay to 4 or 5 parts sand. Clay mortar keeps indefinitely, wet or dry.

BUILDING THE BRICKWORK

Set the first course of bricks very carefully. Their position and stability affects how easy it is to build the whole structure. Mortar courses should be as thin as possible, less than ¼". Arrange bricks so the corners interlock and without straight-line vertical joints more than one or two courses high. Check each course carefully for level using a builder's level. It's important. (More images on pages 51–54).

As you build, clean off surplus mortar that squeezes out between the bricks on the inside of the Heat Riser; do this very carefully with a rough cloth without disturbing the stability. Finally, clean out the Burn Tunnel very thoroughly to remove every vestige of mortar that could affect gas flow. Fuel needs to fall freely into the Feed Tube, so make sure no edges of bricks protrude into the tube.

You want the Heat Riser to extend up nearly to the top of the barrel. So measure the height of the barrel in advance and make sure the courses of brickwork fit that dimension closely. If the gap above the top of the Heat Riser is less than 3 inches, it may be too tight, and the combustion gases will have trouble with their exit. Conversely, if the gap is too deep, the cooking surface (the top



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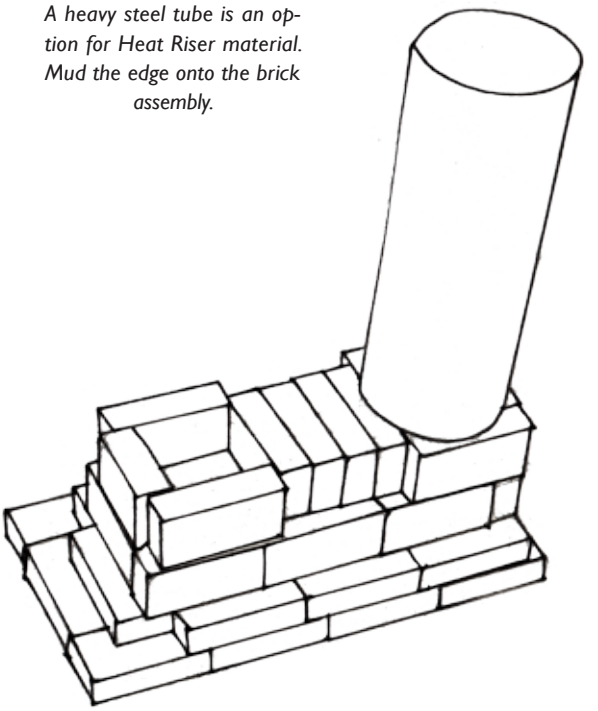
of the barrel) may not get hot enough fast enough to cook on. To get just the right height, you have some flexibility in using thicker or thinner mortar courses and in how high you place supports for the barrel, using broken brick or tile plus the mortar seal. Make the top of the Heat Riser slanted steeply, (at least 45 degrees) by building a cob ring outside of the brick, or on top of the insulation, or on top of the Heat Riser. Use sand-clay, about 3:1, without straw.

It is possible to build the Feed Tube and Burn Tunnel out of brick and to use steel tube for the Heat Riser. Steel in that position is much more durable than if it's used where more oxygen is available farther "upstream."

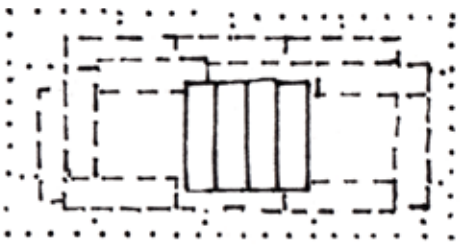


A heavy steel tube is an option for Heat Riser material. Mud the edge onto the brick assembly.

TIPS ON LAYING BRICK

Brick resists heat better than mortar, so keep mortar courses as thin as possible. The finer you sift the sand and clay, the thinner the mortar courses can be—a single ¼" pebble means the whole course can't be less than ¼" thick.

Make sure bricks have no projections wherever they sit against other bricks, nor projections into the gas stream. Clean off old mortar carefully. Lime mortar usually falls off easily; cement mortar is more difficult, as it sticks tightly to the bricks and sometimes you'll break the brick trying to clean it off.



Brick arrangement for 8" exhaust system. Plan view. Dotted lines represent the first flat course, dashed lines are bricks on edge forming the second course, and solid lines are bricks on edge forming the roof of the Burn Tunnel.

Spalls, cracks, and chunks missing may not be a problem, depending on location. Mix mortar wet, about the consistency of guacamole or custard, so it is easily worked. Clay-sand, unlike lime or cement, is kind to the skin, so you can apply it without tools, though if you have a mason's trowel or a bricklayer's trowel, try building your skill with it. Soak bricks in a container of water before use or they will suck water out of the mortar too fast. You have very little time to adjust, so try to set bricks level and plumb and in place the first time. Remember, mortar is mostly to hold the bricks apart (to stop them from rocking), not to glue them together. Before ending work each day or every couple of hours, stuff mortar into remaining cracks and holes, then smooth it all down with a coarse damp rag (burlap is ideal) or a big coarse plastic sponge.

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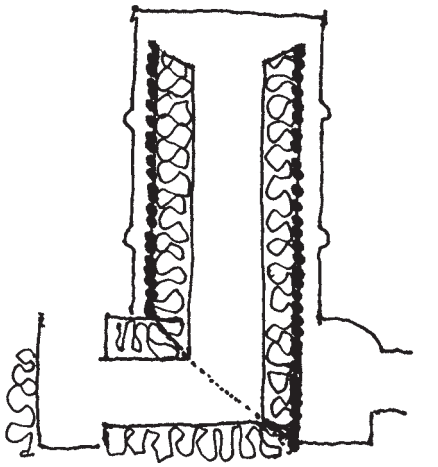
ADDING INSULATION

After the combustion chamber (including the Heat Riser) is constructed and any protruding mortar inside is smoothed off, you can apply insulation. First build up a circular base on which both insulation and the Heat Exchange Barrel will stand. Use whatever is at hand: broken brick, chunks of old concrete, rocks, etc. The base needs to be airtight, so cob everything together. Check the height with a level and tape measure.

The insulant mixture needs to be in a cylindrical container surrounding the Heat Riser and fitting within the Heat Exchange Barrel, but extending down to the level of the bottom of the Exit Flue. A standard electric water heater tank is about the right size if you cut off both ends. If you don't have a water heater tank, sheet metal can be rolled and wired together.

Recently, we've been using ⅛" or ¼" hardware cloth (steel mesh) formed into a rough cylinder and wired together. It's fairly easy to lightly pack the insulation inside it to maintain its cylindrical shape. At the top of the insulation, make a little cap of



Insulation container. Note that the insulation in the container extends all the way down to the ash pit. The insulation cap can slant either up- or downstream and prevents ash accumulation.

Photos: Art Ludwig

(Left) Art Ludwig wraps a wire insulation container around the brick Heat Riser. (Right) The insulation container, partially filled. (See also the photo of Art's Foamglas Feed Tube insulation in case studies page 106.)

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sand-clay. Kirk Mobert suggests, "Add a little clay slip to the insulation, just enough so that the mix will hold together when you squeeze a ball of it. When you pour the mix in, lightly compact it into the void, just enough to stick it together. If you ram it too hard, it will crush the perlite, making it less insulative." It's important to **maintain the sides of the insulation container vertical** so as not to impede the flow of exit gases.

Remember that the bottom of the Heat Exchange Barrel should be located higher than the exit duct, or you will have to cut a hole in the side of the barrel to get the gas to flow out.

Gases need to flow smoothly through the tight gap between barrel and flue as they enter the thermal storage. There needs to be extra space all around the bottom of the barrel, a ring-shaped channel that collects the falling hot gas and directs it to the flue. This space must be much larger than you think, if you just measured the space per system size. Peter van den Berg says, "It's easy to think you have to make it the same as system size. But remember that the gases are not streaming straight out of the opening. Instead, they are coming from left and right, and from the top. Moreover, in the corners, two streams can't pass there at the same time, so you have to compensate for that."

As this is a prime trap for lightweight ash, make it big enough to get your hand into most of it. This channel needs to extend all around the base of the barrel, dropping and widening from above the Burn Tunnel to the cleanout/ash pit where the flue begins. Shape it with a sand-clay mixture without straw, leaving the sides and base really smooth so a cleanout tool can rake out ash without snagging.

SETTING THE BARREL

It takes two people to carefully lower the barrel over the Heat Riser. Be very cautious not to bump the Heat Riser and knock it out of alignment. Kirk says, "When placing the barrel, I get the stove running with the barrel off, let it get hot, then place the barrel on and move it up and down until it sounds 'right.' You'll need to experiment a little, move the barrel beyond the sweet spot in both directions as you go, as if you were tuning a musical instrument, feeling out where you lose power, and when it comes back in. When you've got it, have a helper wedge it up on the circular base and cob it in, making sure it is absolutely upright.

"Also, I enclose the stove WHEN IT'S BURNING! If something happens (cob falls in or a pipe gets crushed) you will know it instantly if the stove is running while you work. Otherwise, you've got to guess where the problem might be after the fact." Seal around the bottom of the barrel with sand-clay. Now test the stove by lighting a very hot fire (if you haven't already) and feeling for radiant heat off the side of the barrel. Run your hand from top to bottom and around every side, slowly, a few inches from the barrel, feeling with the back of your hand for radiant heat. If there are any cool spots, or if one side is a lot cooler than another, you may need to pick up the barrel and reposition it to correct the situation.

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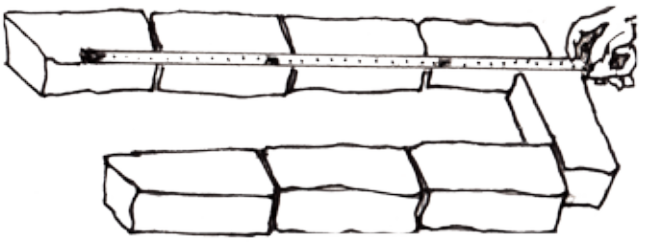
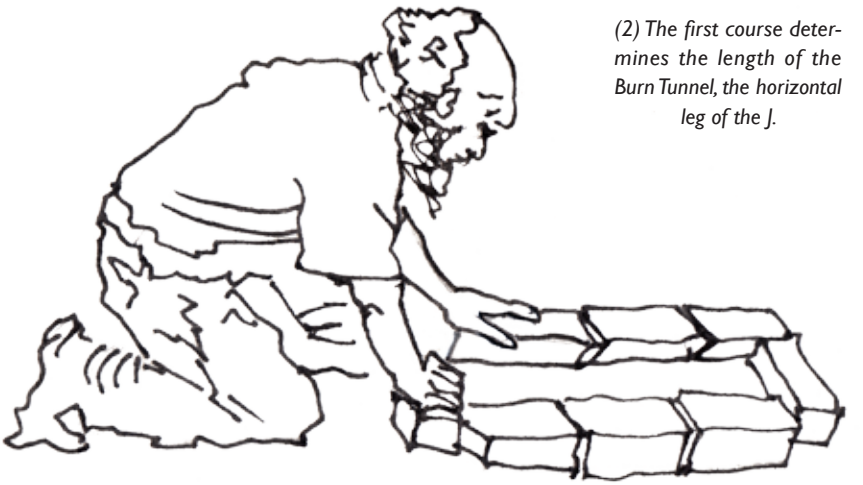
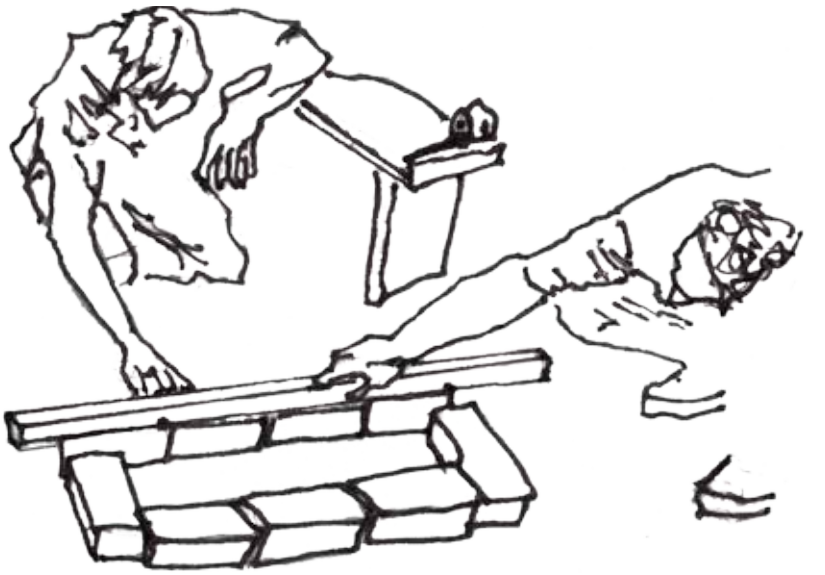
Construction Sequence



(1) The first course of bricks in a mock-up directly on the ground. Bricks are laid flat, with clean sides facing up and, for good gas flow, into the center. This shows the base of the Burn Tunnel. In the actual stove, this course is set on a masonry floor or a very level bed of brick, which may or may not be on a bed of insulation, depending on the design.



(2) The first course determines the length of the Burn Tunnel, the horizontal leg of the J.



(3) Level each course as you build. Maintain the same width all along the channel.

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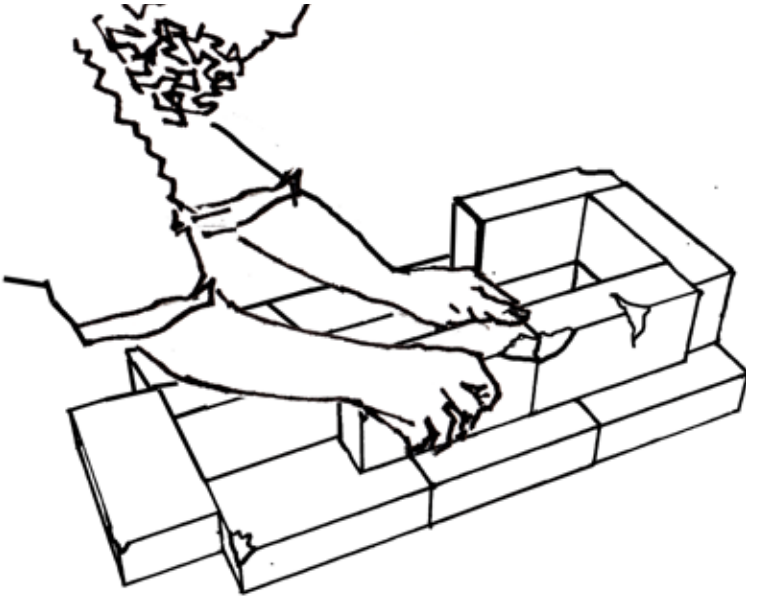
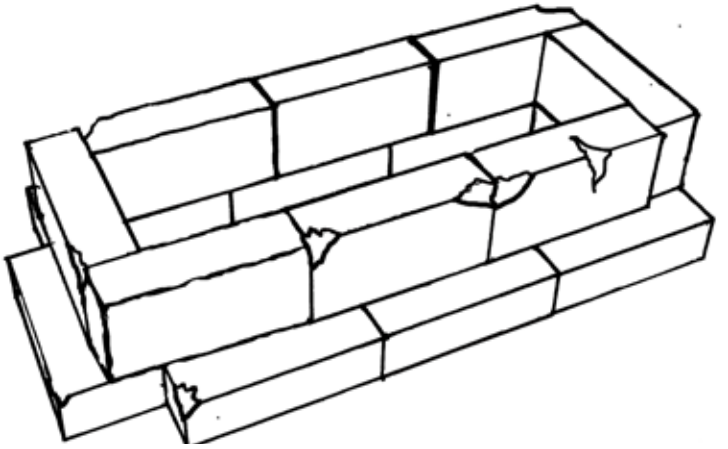
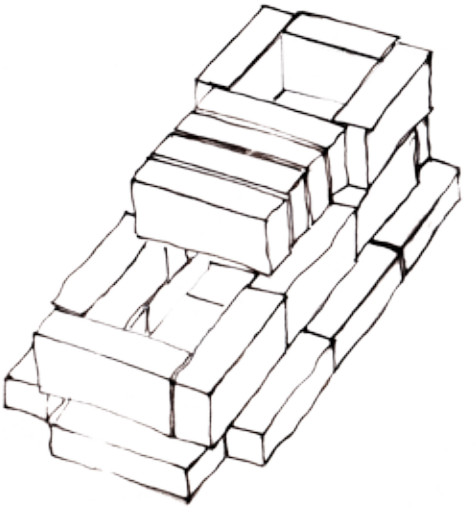
(4) The second course for this stove is on edge; check for level, vertical, and square. Lay bricks in a running bond, each brick spanning a joint below it.





(5) Provided a good face of each brick looks into the combustion zone, imperfections in other parts of bricks are less important.

(6) The bridge of brick over the Burn Tunnel is a good place to put your better brick, stacked on edge in this case.



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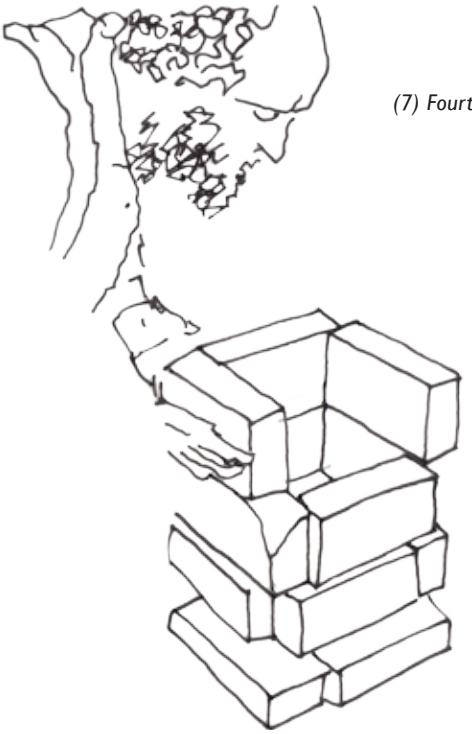
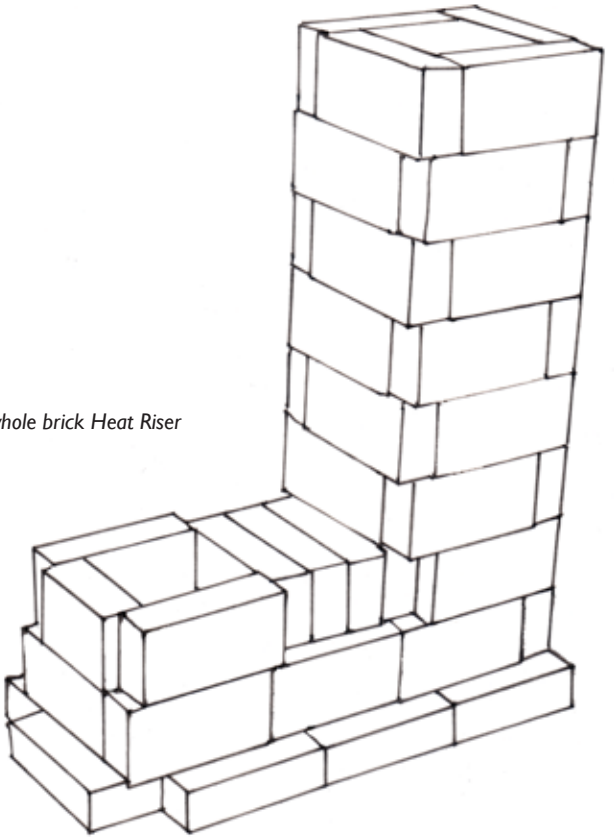


(7) Fourth course going up to form the Heat Riser. Check for square, level, and vertical.



(8) The whole brick Heat Riser

Photo: Chris Reinhart

(9) A brick Heat Riser under construction. A fortress of brick is mortared in to create the Manifold void and to support the barrel. The Feed Tube is reinforced with buttresses of cob and should be held together with a wire ring.

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(10) The insulation around this brick Heat Riser is contained by wire mesh, held with wire. A slanted sand-clay cap at the top few inches will hold the perlite in. There's just enough room to use hands to fill the insulation nearly to the top.

Photos: Art Ludwig

(11) (Left) The slant of the top of the insulation container helps the ash fall back down the Heat Riser where it is easily cleaned out.

(12) A sand and clay cap a few inches deep holds the insulation in. Notice the slant inward, preventing ash from accumulating on the top of the Heat Riser.

This surface should be smooth. We've seen stoves that slope either direction. 45 degrees is probably sufficient and may make it easier to calculate the distance to the top of the barrel. (See more of this stove in Art Ludwig's case study, page 107.)

Notice the round plinth or fortress of cob surrounding the barrel's base. Inside that base is a large void for the gases.

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INSTALL THE EXHAUST PIPE

Draw out on your floor the shape of the heat storage you want to build. Set a layer of rocks in damp cob to begin with, and then place your exhaust pipe on top of the rocks.

The exhaust pipe may be made of metal duct or stovepipe, aluminum or steel. It can also be a brick or adobe tunnel, carefully smoothed inside to help the gas flow. Lay out the pipes beginning at the stove end, facing the male ends of the connectors upstream toward the fire. This way, if there's a condensation drip in the outdoor part of the pipe, it can't run out at the joints, but can be caught in a creosote trap at the bottom of the vertical stack, where there should be a cleanout. If the flue passes outside through a wall, build it to drain outward as protection against condensation running in from the outdoor stack. If you are simultaneously building a Thermal Battery and a cob wall, build in a pipe through the wall of equal or greater diameter than your system, so that you can later slide your final flue pipe through it. You may need to reinforce a thin metal pipe to protect it from distortion caused by differential settlement in the wet cob, or better yet, use sturdier pipe or a removable plastic bucket. Make all pipe connections airtight with high-temperature (duct) tape to avoid CO leaks.

Note that in the heat storage—the part downstream from the Combustion Unit—turbulence is not necessary. Any obstruction which prevents a smooth flow affects the burn. On the other hand, exhaust gases move much slower than in a conventional woodstove, so tight bends are less of a problem. For the Thermal Battery to store maximum heat, long residency time and high temperature are both assets.

CONNECTING STOVE TO BENCH (THE MANIFOLD)

Add extra volume at this location, as the Manifold is a prime candidate for ash buildup and blockage. **Leave an ash pit here of at least 3-gallon capacity.** This can be the number-one place for unintended bottlenecks. (Refer to the Troubleshooting section and the brick

Photos: Kirk Mobert

The exit pipe meets the Manifold. Add extra volume at this location, as it is a prime candidate for ash buildup and blockage.

Prop up the barrel when you've found its sweet spot in relation to the Heat Riser.

A cob shelf is carved out to support a firebrick.

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The firebrick spanning the void will help support the barrel.

construction illustrations, pages 51–53, for more details.)

The three-dimensional shape of the transition from stove to bench is hard to describe yet fairly easy to sculpt. Effectively, you're connecting a thin partial cylinder to a fat cylindrical tube at right angles. English has no word for this geometry. The ideal material for the connection is a sand-clay mixture fairly rich in sand and stiff enough that it can't fall into the void. An alternative—if less aerodynamic—approach is to rough out the void in brick, then plaster it smooth inside with cob. We have also used slate or terra-cotta roofing tiles and flattish rocks. The result may look funky but will work fine if you **make sure to leave plenty of space inside.**

To simplify construction, use scraps of ¼" or ⅛" hardware cloth or expanded metal lath or scrap sheet metal. Curve the lath into place to fit the shape using several small pieces, and then plaster your sand-clay very carefully over its surface.

LOCATE CLEANOUTS

You need to put an inspection hole close to where the pipe exits from the barrel and another one at the bottom of the vertical exhaust pipe. You may need others at each bend. The hole at the base of the vertical exit pipe doubles as a primer, into which you may need to put burning newspaper to get the stove started in unusual weather conditions (see Light My Fire, page 59). Each inspection hole may also be used to clean out the flues. The simplest way to build cleanouts is to use a T-junction in standard ductwork or stovepipe, or cut a 1-gallon food can and inset it. Metal caps are made commercially to fit these pipes, or you could make a plug of your own design. Be sure the plug is airtight to prevent gas leaks into the room.

SCULPT THE THERMAL BATTERY

The cob immediately surrounding the pipe should be packed in really tight for good thermal contact and should contain no straw within 6 inches of the pipe. Pack cob very thoroughly between the rocks and tight against the duct, working up the sides of the duct evenly and carefully, adding rocks as you build. Against external or insulated walls, pack in 2–4 inches of perlite-clay for fire protection and to keep the heat inside the building. If the work is done carefully and the bench is protected until it's dry, there's no danger of the pipes collapsing. Straw is only necessary in the cob close to the surface of the bench. Without the straw, the cob may crack or be subject to shattering if it's hit with a heavy object, so put in a good amount for the surface layer, avoiding long stiff straws that might poke out of the surface. Protect the bench with a half-inch or so of a hard plaster. Round-out and reinforce projecting corners of the bench with extra straw in the cob, as they will get dinged and bashed with use. You may want to try a gypsum-based plaster nearest the barrel; metal shrinks and swells with the rise and fall of temperature, as does clay, whereas gypsum is more stable. (For more information on plasters, see *The Hand-Sculpted House* and *Clay Culture: Plasters, Paints and Preservation,* both in Recommended Books.)

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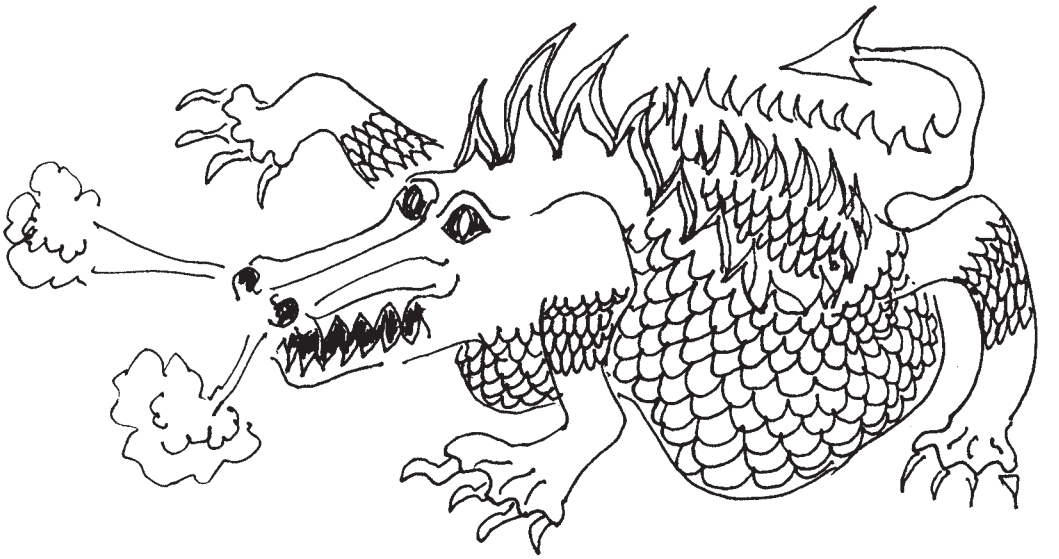

Wales, my native land (which has been described as the Indian reservation of the British Isles), has had a cultural tradition of the importance of home and hearth for over 2000 years. To this day the national plant is the leek and the national animal the Red Dragon, which graces our flag and is to be seen everywhere. It is well known that every cottage had a "house dragon," a cute little fellow who crouched in the inglenook, snoozing but perpetually alert to the need to start a fire and to warm the house. He is called *DRAIG GOCH* (which almost rhymes with fried pork).

Rocket Stoves are the modern dragons, the living heaters that sleep in a corner—unless your house, like mine, has no corners. Like any well-behaved house dragon, mine never smokes (unless he's really young and just learning the hazards of smoking); he growls a little (or do dragons really just purr deeply?) but maintains a little warmth all through the cold northern winter, even when he shows no fire. And of course, unlike the rascally Oriental dragons that actually blow fire from their nostrils, all good Welsh dragons swallow their fire, discharging it with joyful flatulence, cleansed and humid.

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THE FUEL YOU BURN

Keep It Dry

If firewood contains water, the energy produced by burning it is partly used up in boiling that water out of the wood. You lose efficiency dramatically by drying the wood out during burning. The steam so produced can condense inside your flues, rusting them out and dripping from loose joints and inspection holes. So make sure your wood supply is gathered in dry weather and stacked to season in a well-ventilated pile. If cut green—that is, from recently live trees—it should be split open before stacking to allow it to dry out thoroughly for a full year or more before burning; then, in damp climates, store firewood indoors to dry a little more before burning it. Make outdoor wood stacks high and cover the top with something completely waterproof to keep rain off. Keep the sides open so the breeze goes through; thus, wood can continue to dry even in damp weather. Don't throw a plastic sheet over a woodpile; it may trap moisture and condensation from the ground and you could end up with firewood wetter than when you stacked it. If you have any doubts about the dryness of firewood, measure weight loss of a test sample by setting it on your warm stove overnight. If it loses more than 5%, split to thumb thickness and dry it some more.

Kindling Selection

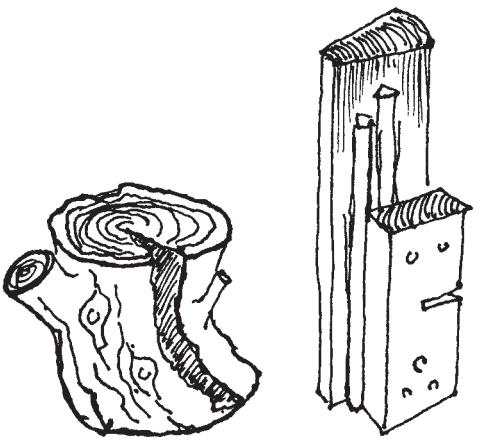
To test the suitability of deadwood as kindling, examine how strong it is. If it doesn't easily break across the grain, it probably has good fiber and will burn well. Kindling should be ***straight, dry, very thin, split, long enough to stand up in the Feed Tube (but not so long that it projects out), strong (difficult to break), fibrous, and roughly square or triangular.*** It sometimes helps if there's a little pitch in the kindling. Conifers such as Douglas fir, pine (except pitch pine), redwood, and fir are good, but red cedar is the king of kindling. Avoid larch (tamarack), hemlock, and spruce. It's tempting to gather twigs, but they have disadvantages. Twigs tend to be crooked and covered in bark. Trees grow bark to protect them from fire and to conserve moisture inside the wood. Splitting firewood accelerates drying and helps it burn better.

If you live in town, you won't need to buy commercial firewood. Your stove will run well on dumpster finds, pallet wood, and the waste that your local arborist generates: straight branches, twigs, and tree trimmings.

Choosing Firewood

When cutting your own wood, choose the straightest pieces, sawing close to knots to leave long pieces easily split from the "not knot" end. Trim branch stubs down flush.

Commercial firewood is normally sold by the cord (a stack 4' x 4' x 8'), yet the energy in it is proportional to its weight, not its volume. So try to buy dense firewood. Heavy hardwoods put out nearly twice as much heat per cord as lightweight species. In a stove with a relatively small Feed Tube, heavier wood such as oak, ash, beech, birch, madrone, or hickory cuts down on how often you need to feed it. Avoid cottonwood, poplar, spruce, hemlock, fir (except Douglas fir), redwood, most pines, and cedar (except for kindling).



Firewood: the Bad and the Good

crooked and knotty	*straight*
short	*long*
fast grown	*slow grown*
thick	*thin*
round	*split*
thick bark	*no bark*
wet	*dry*

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Kiko Denzer points out that his Rocket cheerfully burns small-diameter wood that doesn't even interest his neighbors with box stoves. Plantation thinnings and straight branches are sometimes just the right size without any splitting, and they're light enough you can enroll your kids into collecting them.

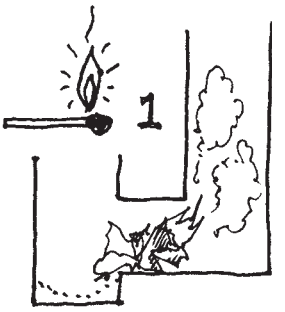
Excessively resinous woods such as pitch pine have trouble burning completely and give off unburnable smoke, which tends to condense inside the flue, clogging it up. Avoid woods impregnated with pitch or creosote, such as railroad ties. Also **avoid pressure-treated lumber and painted wood,** both of which can contain dangerous chemicals. Stay away from plywood, OSB, and other toxic engineered wood products that contain glues.

LIGHT MY FIRE

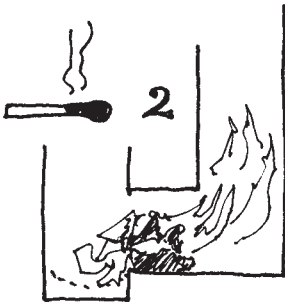
If you're accustomed to lighting fires in box stoves, you're in for surprises. Rocket Stoves function almost diametrically opposite to any kind of stove you've ever lit. The wood stands upright, the air goes down, the kindling goes behind the paper and the firewood behind that. The Feed Tube cools itself so well that you can comfortably sit on the feed barrel. Operation is a brief, very hot clean burn, then you seal the Feed Tube while heat stored in the "battery" slowly warms your home.

First, make sure the draft is leaving your house, not backdrafting up the Feed Tube. If the temperature of the bench gets colder than the outdoor air, a counter-flow can carry air from outdoors down the exhaust pipe and through the intestines to exit up the Feed Tube. This is most likely to happen if you've been gone from your house for a long time in cold weather. Normally, though, you can expect the system to draw air from indoors into the stove. You can tell quite easily by blowing out a match at the entrance to the Burn Tunnel and watching whether the smoke rises or if it falls into the Burn Tunnel.

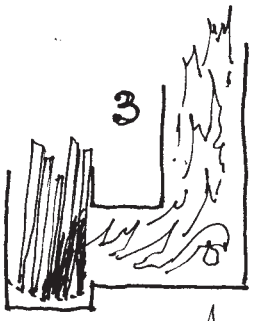
You can also check your indoor stack thermometer. If it reads lower than the air in the room, you may need to prime the system by putting lighted newspaper into the base of the stack.



1. Stuff loose, crumpled newspaper into Burn Tunnel.

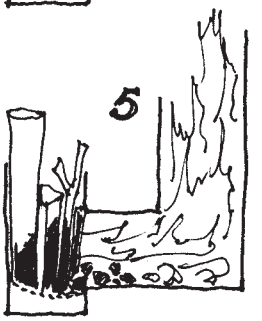


2. When draft is going well, add newspaper balls, not more than half a sheet.



3. Quickly slide in thinnest kindling, thin ends down, tight up against Burn Tunnel and burning paper.

4. Immediately add thicker kindling, all upright and tight against kindling already alight.



5. Now add thicker fuel, gradually cramming the Feed Tube full.

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Use of Paper and Preparation for Lighting

Remember that the Heat Riser makes this thing work, not the exhaust pipe. So in normal operation, to heat the riser quickly, I first prepare a few sheets of dry crumpled newspaper (not tissue, thick or glossy paper, nor cardboard). With practice, you can get away with one or two full sheets at most. Try not to use more, as the clays in commercial paper don't burn and can rapidly build up an ash problem in your tunnels. Then I prepare a handful of very thin, very dry, straight kindling with all of the thin ends together, and the matches. I set them all down on the bench alongside the stove. *Kindling needs to be tinder-dry.* Kindling should begin as *slivers* no thicker than a pencil. Use about half a dozen and graduate to finger-thick as they catch fire.

If there's any question about the dryness of the paper, kindling, or matches, I generally leave them in a warm place overnight so as to be dust-dry in the morning. In damp climates such as the Maritime Pacific zone, a kindling shelf or rack above the stove is a good idea, but make sure nothing can fall off it onto the hazardously hot surface of the stove. Safer, perhaps, is to leave paper, kindling and matches on the heated bench.

Now (**1**) I light one of the newspaper crumples and reach down with it so I can stuff it into the horizontal combustion tube, blowing gently down the feed. I wait until the smoke finds the Heat Riser and I hear it burning fiercely, then (**2**) I drop in the other newspaper crumples so they are at the opening of the Burn Tunnel but in contact with the burning piece. If for any reason smoke comes up the Feed Tube, I blow again gently to give it the right idea until it's drawing strongly up the Heat Riser.

Warning: If you burn large quantities of paper, its lightweight ash may float down the stove's intestines and constipate it. After initial ignition, burn only wood.

Adding Kindling

As mentions, kindling must be tinder-dry all through, pencil-thin, straight, split, splintery, and long enough that it can't fall down into the Burn Tunnel or Feed Tube. As the paper ignites, I very quickly stack a fistful of the thinnest kindling **vertically against the exit from the Feed Tube** so the burning newspaper backs up to it. (**3**) The heat of the newspaper ignites the kindling, which burns upstream of it. Then I add more kindling, tight against the opening and upstream of the first load, which as it burns eats its way back into the new kindling. (**4**) Now I add progressively thicker pieces of wood until the Feed Tube is completely full, pushing the fuel up tight against the entrance to the Burn Tunnel. (**5**) The fire chews backward into progressively thicker fuel. Only the bottom end of the wood should be burning. **Always stoke behind the burning pieces,** load the Feed Tube from the end away from the Burn Tunnel, and completely fill the Feed Tube. If you don't, your stove may smoke.

Ideally, as the bottom ends burn off the fuel, pieces drop by gravity into the Feed Tube. Often they jam up, so you may need to shake them down, sometimes quite vigorously. Logjams can be avoided somewhat by (a) choosing straight fuel without side branches, (b) not cutting fuel so long that it cantilevers itself out of the Feed Tube, and (c) feeding fuel **thick end down** so it doesn't wedge itself into the Feed Tube.

Stoking

You can regulate the power output of the stove and therefore how hot the barrel gets by the thickness of the fuel. If you need sudden heat, use a handful of thin, split, really dry, straight kindling up to the size of a child's wrist. The thinner the fuel, the greater the power output and the faster the stove heats up. Conversely, if you want to be able to keep the fire burning for a couple of hours, you can use thicker—and preferably denser—fuel. There's normally enough heat retained in a brick Feed Tube to keep a single log burning for a couple of hours.

For cleanest burning, fires need to be hot and well stoked. Rockets work best if fired at full load for a few hours each day to charge up the Thermal

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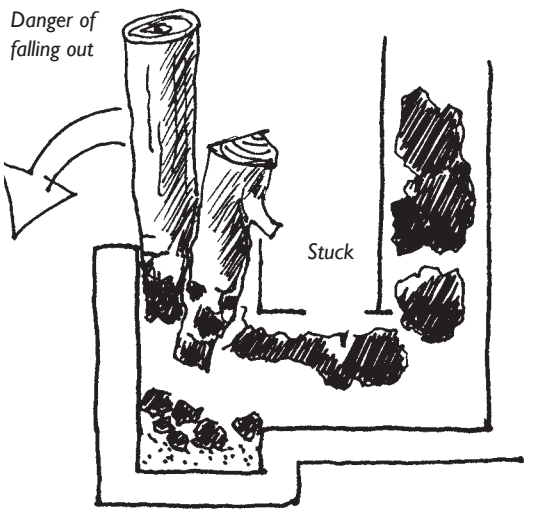
Battery. As soon as the embers die down, close the lid as tightly as possible. This stops the system from sucking air through the bench and cooling off the mass, and prevents heated air being dragged out of your house. To regulate the flow of air onto the fire, over the opening of the Feed Tube I use firebrick or tile, or a flat sheet of cast iron; it is removed for stoking.

Because Rocket Stoves work by gravity feed, the wood needs to be fairly straight, without bumps or side branches which might hook it up as it falls into the Feed Tube. Theoretically, a really straight smooth piece of wood can be quite long and should feed itself into the stove automatically, but in practical terms, it's not advisable to use wood much longer than the Feed Tube. It may burn vertically upwards and fall over, creating a fire hazard or smoke in the house. Worse, if fuel projects out of the top of a Feed Tube, it can ignite outside the tube, flaming up and potentially reversing the fire's flow. At best, you could be smoked out; at worst, it could set your house on fire.



Feed the thick end down.

Here are some situations to avoid. Two or more flat-sided pieces projecting out of the Feed Tube can create a chimney between them, up which the fire can creep against the incoming air. Of special concern would be two pieces of split wood or boards with flat faces, facing each other. Even inside the Feed Tube, try to avoid feeding with flat faces opposing. In Pocket Rockets, a metal stack can get hot enough to ignite (by radiation) fuel that is sticking out of the Feed Tube several inches away. In each case, problems can be avoided by *keeping the fuel length shorter than the Feed Tube* and keeping the cover of the Feed Tube always on top of that barrel, leaving an air crack if needed, but preventing any back-burning.

I keep a chimney thermometer in my exhaust stack inside the building where I can see it, just above where the pipe emerges from my heated bench. I check it regularly. It's a very accurate probe-type thermometer that measures the temperature inside the tube. Because you don't expect high temperatures, it only needs to read between 200 and 300°F. Probe thermometers are a little more expensive but they are very accurate, more durable, and less likely to fall off and break than the magnetized type that sticks to the surface.

The thermometer is useful also because the temperature of the flue gases drops when your stove needs to be stoked. Simply by casual glances at my thermometer, I can see when pyrolysis is no longer happening, which usually means that either the fire is down to embers or the wood is hanging up instead of falling in by gravity. Familiarity with the stack temperature will alert you to inconsistencies in combustion or anything that might be wrong in the system, such as a slowly clogging flue. A stove that normally generates 250°F at the Exit Flue, but suddenly can only be cranked up to 200°F could be evidence that for some reason the draft is not working well.

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Maintenance

This is not a maintenance-free stove. The Rocket is a nonstandardized experimental and whimsical device, which you will probably build for yourself. Each one has a distinct personality that demands regular attention, monitorin, and maintenance. There are a few things you should check on quite regularly. Maintenance involves mostly keeping all of the tubes clean, a little like the way eating a high-fiber diet cleans out your intestines.

Clean the ash out of the combustion chamber regularly. If you ritualize cleaning it every Sunday morning, for instance, you are much less likely to forget. If you don't, it may gradually clog the throat of the Heat Riser, or worse, ride on through the system and block another tube which is less easy to clean out. Use something hooked like a potato masher or a kitchen ladle to pull ash out of the Burn Tunnel, then scoop it out of the Feed Tube with a cup. Or, after making sure the system is really cool, employ a shop vacuum. First, push your hand down into the ashes to make sure they are cool enough to extract. If you can't keep your hands in them, you could have a dangerous situation. Once, loading warm ash into a plastic bucket, I ran to the phone, leaving the bucket to melt and the hot ash (containing live coals) to spill out onto a wooden floor. Thankfully, the phone caller had the wrong number or *my* number could have been up. Take ashes (cooled down) back to the woods where they originally came from.

Inspect the horizontal flue in your heat storage every month or two by opening the cleanout and putting in a small mirror and a flashlight. If ash or soot is building up in the pipe, it can be cleaned either by using a vacuum or by pushing a chimney brush through the system. Not having either, I use a long flexible bamboo cane, freshly cut, with twigs and leaves still attached. If you use other vegetation, choose something very fibrous and flexible—you don't want it to break inside the duct. Metal pipes are fitted into each other with the male end facing upstream, so it may be easier to rod out the system toward the stove, not away from it, for easy extraction. If you use a cloth attached to flexible pipe as a flue cleaner, make sure the cloth can't fall off inside the flue—you may have real problems getting it out. Clean the vertical stack at least twice each burning season to remove soot and creosote unless you get little result, in which case, once.

Photo: Leslie Jackson

One of the longest-running (12 years) Rocket Mass Heaters in southern Oregon. The stack of small, straight, dry fuel measures 4' x 2½' x 1' and lasts 7 winter days. Note the drying rack well above the barrel's top.

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Cooking on the Rocket Stove

Rocket Stoves for cooking, using the same basic principles described in this book, are used worldwide, particularly where firewood is scarce and the cooking is done inside, necessitating a smoke-free, highly efficient stove. This book mostly covers stoves to heat people, with a few cooking options. The World Wide Web contains a lot of information on Rocket Stoves, including lively and timely discussions, research findings, and instructions on how to build a number of different designs. Simply feed the string "Rocket Stove" into your favorite search engine.

Photo: Flemming Abrahamsson

Tiny Rocket Stove for making coffee in Flemming Abrahamsson's office (see section drawing, page 86).

Once you have a functioning stove in your house, you'll probably find unexpected uses for it. Our friend Calleagh Ferrara gave birth to her baby on her Rocket-fired cob bench.

You can empty the top of the barrel as a food dryer, or for raising bread dough or for brewing, by using the gentle residual heat after the fire dies down. It's easy to dry things like seeds and sliced vegetables overnight this way. And of course, there's cooking.

If your primary goal is a cooking stove, you will have to compromise its efficiency as a mass heater. More heat to the cooking surface means less to other places, and when you're *not* cooking that extra heat chiefly heats the air *above* the stove, with loss of radiant heat from the sides and of stored heat in the Thermal Battery. Otherwise, if you chiefly need a heating stove, the top of the barrel is most suitable for simmering or keeping things warm. It works best as a slow cooker for beans, grains, and soups. My own Rocket Stove is not so good at delivering a fast cup of tea in the morning, or for frying, which needs a much higher temperature, but it makes the best toast I've ever tasted.

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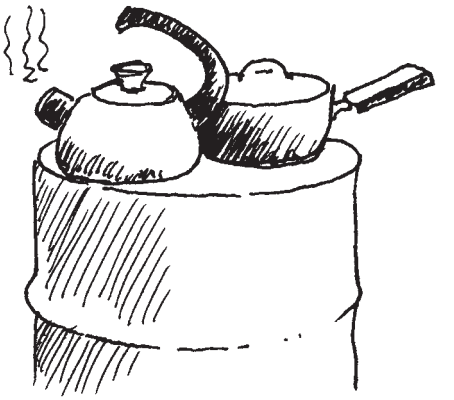
If you keep a teakettle on top of your stove, you'll have a ready source of very hot water. Even when it's not boiling, it is preheated and much faster to bring to a boil on a gas or electric cooker.

It's also possible to get food boiling on the gas stove, and then put it on the Rocket where it maintains temperature without a vigorous boil. This way you don't lose volatile oils, and you maintain more flavor and enzymes while saving fossil fuels.



With larger Rocket Stoves—a 30-gallon barrel or bigger—a removable stovetop oven can be used for baking. The best trick I know is to buy a $1.99 roll of lightweight aluminum kitchen foil and carefully wrap it around to form a little beehive with several thicknesses of foil, shiny face in, to reflect the radiant heat inward. Tuck the end of the roll over the lower edge and crimp it together with your hand, then crimp a loose handle at the top. You have an instant oven that will bake good bread, but be sure to support the bottom of the loaf above the barrel top so it doesn't burn. When not in use, the oven can be hung up indoors or outside.

In September–October when there's still a lot of surplus fruit and vegetables available, yet the humidity is up (especially at night) and the temperatures are dropping, we use our Rocket as both house heater and food dryer. You could set up a multi-rack food dryer with stacked screens that sits above the barrel, raised and lowered by a pulley (see photo, page 14).

Tinker around. Any burning or cooking device needs practice. Can you remember the first time you tried to cook on gas or electricity or a pump-up camping stove? It took time to learn to operate the new machine. So play with your stove a lot. Try improbable things and see what happens. Experiment and let us know the results. You may discover something completely new that nobody has ever thought of. If you do, we'll put it in the next edition of this book.

Aluminum Foil Stovetop Oven

Purchased by Johnathan Yelenick, johnathan.yelenick@gmail.com #11023292

Will Rocket Mass Heaters heat every kind of building?

They are much more suitable for some uses than others. Keep in mind the trade-offs and limitations.

Heating by these stoves is characterized by quite a lot of convection, a major amount of conduction, but very little useful radiation, except from the top of the Heat Exchange Barrel. The release of heat from storage is slow and gentle over many hours but the stove needs regular attention while it burns.

Compared with a fireplace, which heats you only by radiation and only while it burns, or a metal box stove, which radiates heat from the sides and top but is too hot for conductive comfort, **this is a cuddle-up device.** You can stay warm by being in contact with the storage mass for up to 24 hours after the fire has died.

The issue is not whether it will heat a building. The building couldn't care less. The issue is whether any heating device provides comfort to the people who need it.

If you live in a big, leaky, or uninsulated house, convected heat may be lost before it reaches you. Consider how to get more fast radiation that you can stand in front of to warm up. You'll use a lot more fuel, but that's the price of a house that's big, uninsulated, or leaky. Consider a big Pocket Rocket (see Adaptation & Other Kinds of Rocket, page 80), or another type of high-radiation stove with an insulant lid, or an efficient wood-burning stove.

Rocket Stoves need fairly regular attention and stoking and are best suited to someone who is normally home several hours a day. They are particularly useful if contact heat is arranged, e.g. through the seat at your desk, or where you do phone work or handcrafts or read. And of course, if firewood is expensive and you are trying to put out less greenhouse gas or air pollution—which is what we all need to do anyway.

Where would I choose not to build a Rocket Mass Heater?

Buildings that are irregularly occupied, such as churches, meeting halls, etc., need to be heated rapidly and don't benefit from long-term stored heat. In large houses with many rooms in very cold zones where heat needs to reach rooms distant from the stove, it might make sense to heat selected rooms by forced hot air. In a work space such as a carpentry shop where you seldom sit down, it might be better to have a stove that delivers a lot of radiant heat in place of storing heat, so you can quickly adjust your comfort by moving closer or farther from the stove. In outdoor rooms or living spaces that are not well sealed, such as teepees, tents, etc., the air heated by a Rocket would leave the building before you got a chance to enjoy it. Better maybe to put in a stove that delivers high-temperature radiation, such as a barrel stove or a Rumford fireplace.

Are Rocket Stoves code-approved?

This stove is different from the burning devices that the fire codes are written for. The Rocket's Exit Flue is considerably cooler than box stove chimneys, for example, so concerns about materials used for exit tubes may not apply.

Before installing your stove, you should know your local code for wood-burning devices. Although you may not follow it to the letter for this type of stove, nor intend to inform the building department, codes sometimes help us make wiser choices.

In some areas, this stove may present difficulties with the fire department, as it is not certified and officials may not yet be familiar with it. So take

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them a copy of this book—it's a good investment. Remember also that these stoves have not been in regular use long enough to determine the real risk of chimney fires, so inspect your chimney often. What's important is that you do everything safely. Far more significant than legalities are concerns about fire safety and preventing toxic gases in your house.

Erica and Ernie Wisner have done quite a bit of legwork on permitting these stoves, and share this excerpt from their "Official Friendly Flyer":

> Building permit offices may be puzzled by the notion of an earthen masonry heater. Obtaining an official building permit may require some research and collaboration with local building officials. A masonry heater (ASTM standard 1602-03) is 'neither a woodstove nor a fireplace' (OR Interpretive Ruling 93 - 47). Site-built masonry heaters have long been exempt from EPA regulation, by weight (over 900 kilos/1980 lbs). This exemption reflects the historic performance of masonry heaters: by design, they produce comfortable, clean, efficient heat, with minimal environmental impact. The masonry mass stores and slowly releases the heat from a short, hot, clean fire. This reduces both fuel needs and smoke released per fuel weight compared to other solid fuel burning devices. Some jurisdictions ask owners to submit plans for a mechanical permit (verifies weight support, and clearances) before installation. Rocket Mass Heaters often weigh 3 to 6 tons (5,000 to 12,000 lbs); but are typically built as a low bench with dead loads of less than 150 lbs/square foot. Vertical column configurations need more substantial footings; see local rules for masonry walls or chimneys of a given height. Properly composed earthen masonry for Rocket Mass Heaters is similar to traditional masonry heater materials.

I'm concerned about greenhouse gases. I have read that woodstoves are out-of-date, messy, and a big source of pollution and greenhouse gases. What is my best heating choice for the environment?

While these claims are generally true, new woodstoves have been much improved over the past few years, burning efficiently and giving off very low emissions. But there is still a great deal of heat wasted with the conventional wood-burning stove, the box stove. That's why we invented one that is extremely efficient and heats your body before heating the house. For home comfort, passive solar should definitely be everyone's heating choice, but you may have an existing house that is not passive solar and can't easily be modified. Most of us live in places where at least some back-up heat is necessary, or we may want a hot seat to warm up on. Most other heating options are quite literally terminal for our descendants—oil, gas, electric—(from oil, gas, or nuke)—or terminal for other species (e.g. dams on salmon rivers). Wood fuel comes from sunlight and replenishes itself every few years as it grows, reabsorbing the CO that your stove gives off.

But what if you're a renter?

Several of Cob Cottage's offices and smaller buildings have been rented spaces. One was a conventional building with a wood floor. You'll have to practice talking nice to the landlords. Prepare some snappy photos of gorgeous sculptural Rocket Mass Heater bench assemblies and tell them you can increase the value of their house. You could present the landlords a copy of this book. They may go for it. Cob Cottage's landlord graciously conceded, provided we agreed to demolish our stove when we left and replace it with the same space-consuming black-box wood-burner that was there before.

If your rented house has a wooden floor and/or walls, you need to take appropriate precautions not to burn it down. In the house that contained Cob Cottage's office, where there was a 3-ton double bed Rocket-heated cob bench, the combustion assembly was raised above the floor about 6 inches with clear space underneath it, and insulation was built into the base of the entire stove. We reinforced the floor joists with a stout post in the crawl space beneath the stove. To protect a wall of stud construction or any other burnable material, install between the wall and the storage bench at least 4 inches of high-temperature insulation. Keep the Combustion Unit at least a foot-and-a-half from the wall with an air space in between, and face the wall with aluminum foil, shiny side toward the

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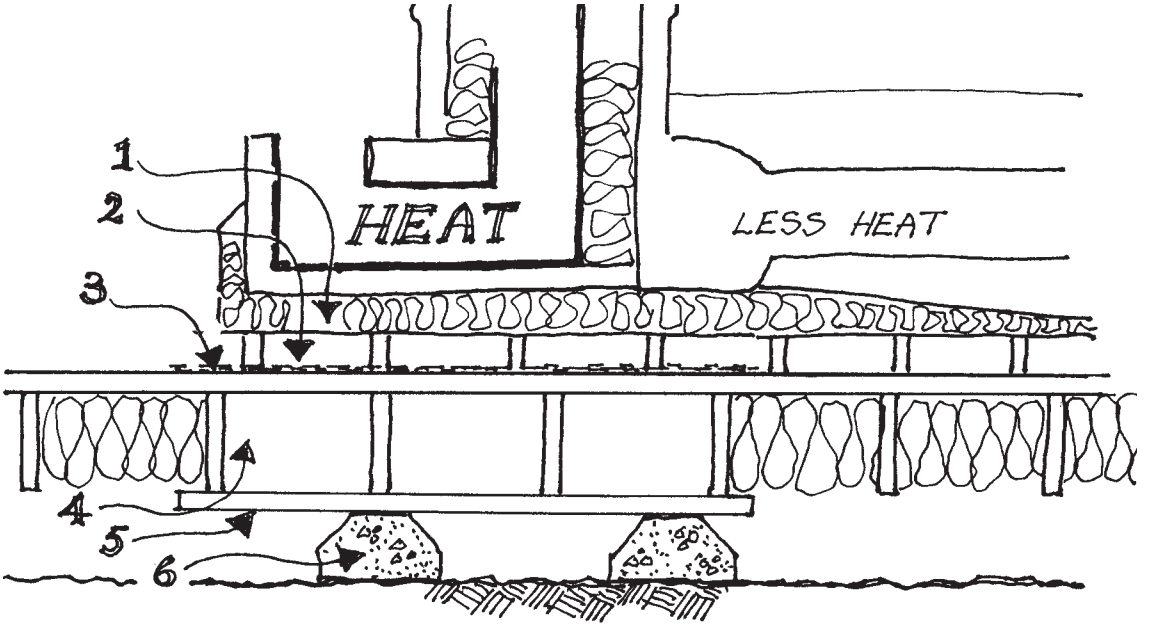

8" Rocket Stove built over a wooden suspended floor
1. *4" mineral-clay insulation, suspended on 4" brick on edge*
2. *4" airflow space*
3. *Two layers of crumpled aluminum foil glued to floor surface, shiny side up*
4. *Floor insulation removed below Combustion Unit*
5. *2" board for reinforcement*
6. *12" concrete pier blocks wedged in tight*

stove. To help reduce temperatures at the wall, you could install a fresh-air intake pipe between stove and wall as a cooler. This also prevents the stove from sucking warm air out of your house. (Refer to more safety precautions about building on a wood floor in Fire! Fire! on page 77.)

How often do I need to feed it?
Fairly often; dragons like to snack regularly. It's one of the delights of the Rocket (for those who enjoy fiddling with a fire). Normally my 8-inch-diameter system needs attention every 40 minutes to an hour, when burning lightweight wood such as alder or maple. With ash or oak, it happily runs a couple of hours without stoking.

Can I leave it to burn all night?
It's almost impossible to burn any woodstove all night cleanly. The box stoves where you throw in a log and close down the air supply pyrolyze the wood (that is, bake the chemicals out of it), so it smolders all night, generating air pollution instead of heat. Most of the problems with air pollution from woodstoves come from nighttime smoldering. By contrast, Rockets work well at burning wood fast and clean, and depend upon separate heat storage to keep your house snug. Before you turn in for the night, you let the fire burn out and seal the air supply, then light the stove again the following day, which is easy.

How long does a cob bench maintain heat?
Cushions on the bench will insulate it well. When I rise in the morning I first fold back the bench cushions to allow the Thermal Battery to warm up the room. Simply by doing this I sometimes see the room temperature rise 2–4°F, even after 18–24 hours since the last fire. If I keep the cushions on the bench, it's still warm enough to be comfy a day later. Bigger Thermal Batteries, such as our Rocket-fired double bed stay snug 2 or even 3 days after a 4-hour burn.

But I only have short chunks of firewood.
They burn fine, but you need to stoke more often, and the Feed Tube needs to be quite smooth so they can't jam together and hang up. You still need long kindling for lighting.

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Does it need a direct outdoor air supply?
Any stove burns oxygen. But it doesn't selectively extract oxygen from your house, leaving you gasping in a room full of nitrogen. It sucks *air* out of the house, not just oxygen. And no, you won't be airless, because as air is sucked down the Feed Tube, the slight vacuum created in the room pulls in "replacement air" from elsewhere. In cold climates or leaky houses this results in drafts, usually around the bottoms of doors and windows. A separate air vent serving the stove can cut down on these drafts. A 4-inch pipe should be very adequate. Cover both ends with ¼" metal mesh to keep animals out. Provided your doors are well-sealed, it may be sufficient to draw cold air down from upstairs, through the many small cracks in a building, through ceiling vents from an attic, etc.

Can I run ductwork through the floor or interior walls?
Almost certainly, unless you already have a poured concrete or a wooden floor. Even in the chilly British Isles, the Romans 2000 years ago heated their villas by hypocausts. A hypocaust is a series of under floor ducts carrying hot gases from a stove. The Romans used sandstone slabs for flooring, set up on stone pillars above a heated crawl space 2 or 3 feet high. Today, it might be more convenient to use metal pipes cast into an earthen or concrete floor or laid in dense cob under brick, tile, or flagstone. Remember to put in adequate provision for cleaning out ash and soot, and to guard against entry by rodents.

How much time should I allow for construction?
What takes the most time is preparations—assembling and organizing materials and tools, and designing the stove. When everything is ready, two people can easily build a good stove in a weekend, or in a day with practice. The thermal storage might take longer to complete, depending on the size.

How soon after building it can I fire up my stove?
The best way to get it dry is to put several short, hot fires in it and gradually heat it up. The beauty of working with a lot of sand in a sand-clay mix is that the sand stabilizes the mix and prevents cracking, so you don't have to wait a long time, just dry it gently.

How can I make the old barrels not look like old barrels?
You can cover the barrel partially with sculptural cob or welded artwork. There may be less toxic stove paints with which you could paint it a cheerful color, or you could polish it with sandpaper or buff it with a wire brush-head on an electric drill. Alternatives to barrels include a cylindrical water tank, or a custom-built brick column, as is common in Denmark. European mass stoves are often covered with decorative glazed tiles.

How long does the barrel last? Does it burn out?
We've never seen one burn out, though we haven't run the same one for more than 12 years. With all the oxygen used up, as long as you keep it dry it can't burn from inside nor rust from outside, so it should last a very long time.

Won't my kids burn themselves?
Probably not. We don't have a single report of a child being burned. At baby height the barrel temperature is quite low—perhaps 200–300˚F, much cooler than most metal box stoves. Unlike conventional fireplaces, the fuel can't roll out, and no coals are exposed.

How small can I build a stove? Is this scalable downward?
We've built systems down to 4 inches in diameter and have found that the smaller the system, the more serious the problems. With specialized parts Peter van den Berg has built them in his lab (see his case study, page 110). We recommend you don't go below a 6-inch diameter (30 square inches). We give step-by-step instructions for building an 8-inch system, and we recommend building that model before experimenting—but in milder climates, say where temperatures don't normally drop below 20˚F, you can easily turn your tiny cottage into a very hot sauna. Experience so far suggests that using the model described, a 6-inch exhaust duct heats only a tiny space in a rather mild climate. So in colder temperatures or in a larger house, you need an 8-inch system. If the system is bigger than you need, you can simply run it for less time, but a too-small system is more difficult to remedy.

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The stove smokes into the house.

• First, make sure there are no obstructions. Clean out the Combustion Unit and all horizontal ducts. Start from the fire and move down the gas path. **Check for ash to be cleaned out of the Burn Tunnel.**

• If smoke gradually develops over days or weeks, there could be a build-up of ash somewhere else.

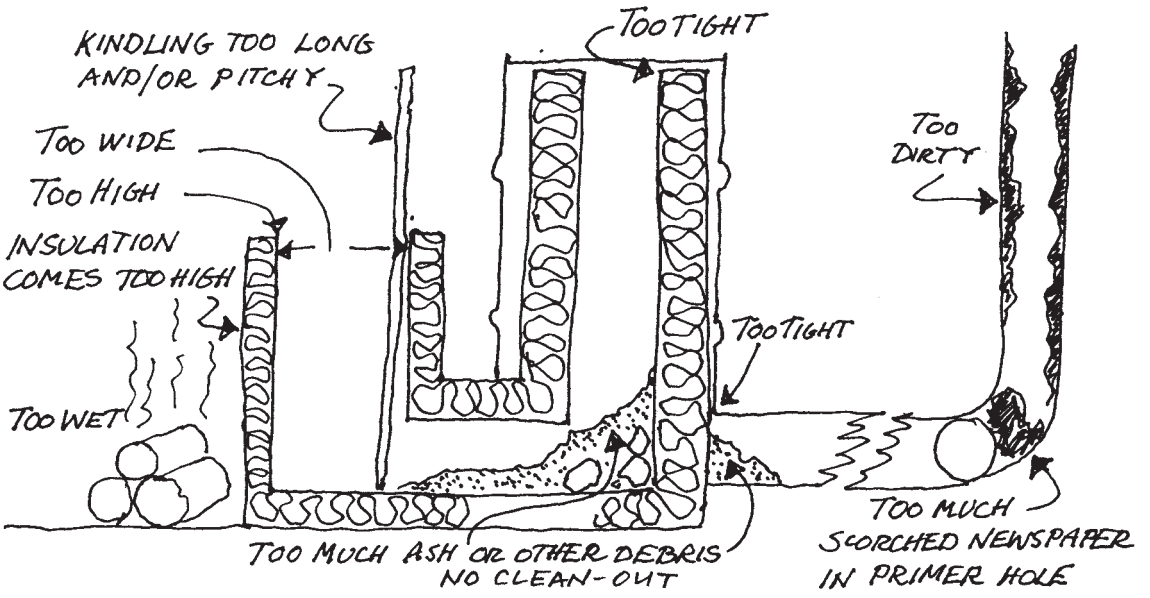
• The gases could be squeezed too tight as they flow over the top of the Heat Riser, or there could be an ash buildup there. Note that we now recommend keeping the angled shelf at the top of the Heat Riser as narrow as possible. Raise the barrel slightly, and use Kirk Mobert's barrel setting method (see page 50). Another likely problem is that indescribable "manifold" shape after the Heat Riser, as the gases enter the bench pipe. You may need to carve that out bigger. Kirk says this is the NUMBER-ONE problem experienced by Rocket Mass Heater users. "It's where I look first when I'm troubleshooting."

• More than once, we've been phoned by someone who, on investigation, found residual **unburned newspaper** in the primer hole.

• Once, a dead wood rat was sadly mummified in the tunnel of the heated bench. Another time, following a summer of inactivity, there was a **mouse nest** clogging the exhaust pipe. A piece of ¼" wire mesh over the end of the flue will prevent animals from climbing in.

• Because the Combustion Unit is **pushing** cool gases up the stack, whereas with box stoves the hot stack gas itself is pulling gas upwards be extra careful to ensure there are no obstructions in the exit stack. For instance, a spark arrester on the exit could block with soot unnoticed, or possibly unburned paper from the primer hole could fly up the stack and lodge there.

Looking for trouble? Try these places.



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• If you're getting smoke there's a chance of toxic gases such as CO backing up and escaping into the house.

• If cleaning doesn't improve things, try making the Heat Riser taller, mounting the barrel on additional bricks.

• Are you certain your fuel is **completely dry**? Make sure it is. Split it thin, weigh it, bake it in the oven or on the bench, then re-weigh it.

• Unburned carbon can be deposited and can accumulate slowly, gradually building up like black hoarfrost inside the pipes, especially if you burn pitchy wood or conifer bark. Clean it out from time to time.

• Occasionally something falls down the Heat Riser, such as mortar from between the bricks.

• Perhaps some wet mud fell into the tube as you sealed the last hole. So **clean out the Burn Tunnel** very thoroughly all the way to the end.

• Experimental liners for the Heat Riser may break up and fall inward. An example is the ceramic tile drains we tried in the early days. They can't take the thermal shock so they tend to explode, showering shrapnel down the hole.

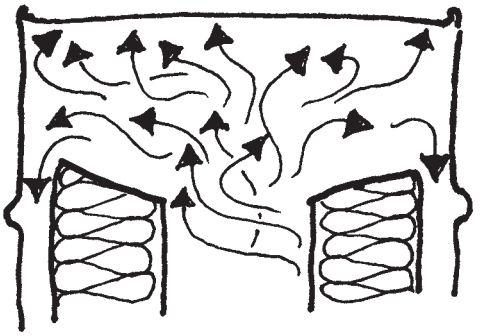
• The bench was **built with a bottleneck** in it. Perhaps there were too many right-angle bends, or a flimsy metal pipe collapsed during construction.

• If the **Feed Tube was built too wide**, it has the same effect. You can test by sliding a loose brick or sheet metal across the top of the Feed Tube. If all smoking stops when, for instance, you have it one-third covered, provided there's still a good draft you could make the brick permanent.

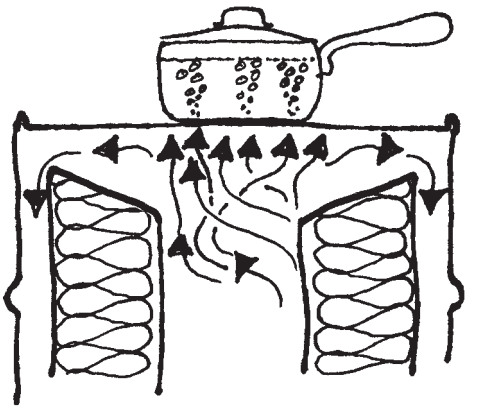
• Earlier editions suggested that proportion H (see Dimentia & Proportia, page 28) be only 1½" wide. Some wood species create condensates, soot, lightweight ash, etc., which accumulate inside the barrel and can impede gas flow badly. Make that gap minimally 2", preferably 3".

• Sometimes, using **long pitchy kindling** cause sthe burn to rise up the Feed Tube. Fire seeks out the easily flammable dry pitch and creeps vertically up the wood toward the top, sometimes burning outside the Feed Tube. If you use pitchy wood, keep it shorter than the Feed Tube. If the fire still burns up the hole, fill the entire Feed Tube with fuel, constricting the ability of the stove to burn backward up the fuel. Keep a brick handy to cover part of the Feed Tube opening if there's a persistent problem, or if the Feed Tube has a lid, experiment with how far closed it needs to be. If it persists in burning backward, a good shaking to help fuel fall in is likely to improve things.

• The first time you light your new stove, don't expect immediate success. Don't be downhearted if it smokes like crazy and it's hard to get a draw. With any new masonry stove that's still cold and wet when first fired, there will be an adjustment period. Use the primer, fire it up with the driest, thinnest wood you have, and be patient. It may take several hours for it to start burning really well.



Heat dispersed all over



Heat concentrated in center

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I can't get a quick boil.
This means the temperature of the top of the barrel just isn't high enough. Good tea is worth waiting for, but if the problem is a cool cooking surface, the top of the barrel may be too far from the top of the Heat Riser, so the heat produced is being scattered across the whole surface. You may want to **bring them closer together** to concentrate heat in the center.

For fast cooking, **stoke with thin-split wood;** it burns faster. We've seen Rocket cookstoves get hot enough in the center to glow orange.

When cooking or boiling water, some simple things to remember include:

• Burn dry wood, split thin.

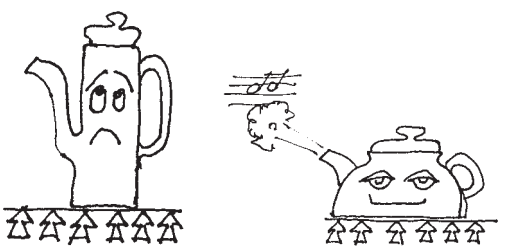
• Cast-iron or any heavy cookware heats up slowly; stainless steel loses heat slowly.

• Don't put in more water than you immediately need.

• Always **put a lid on** the pot; it can make a huge difference in how long it takes to boil.

• If the pot tends to be sluggish, try laying an insulated nonflammable potholder on top of the lid.

•The bigger the surface area of the bottom of the pot, the more heat can get to it. Tall narrow teakettles take a long time to boil; use a short wide pot.



There's condensation in the exhaust pipe and ductwork.
Clean burning of even the driest wood produces water vapor, but you should have enough heat in most parts of your pipes to prevent condensation, at least inside the building. Outdoors, an uninsulated metal exhaust-pipe stack condenses liquid water any time the air temperature is low, particularly if your heat storage is really efficient, lowering the exit temperature of the gases to near condensation point. Condensates may be pure water or may contain a little creosote.

A newly constructed stove takes days—even weeks—to dry out, so don't despair if there's a lot of condensate during that time.

Most likely you are burning wet wood. How can you tell if your firewood is too wet? Easy. Weigh some straight from the wood stack. Split it thin as a finger, leave it on the top of the warm stove overnight, and weigh it again the next day. If you don't have an accurate scale, you can take a great armful, at least 20 pounds, onto the bathroom scale with you and subtract your own weight. Or if you have only a postal scale, use a small sample. You'll get a fairly accurate reading. More than 10% weight loss in a night means your firewood was disastrously wet. Even 5% lost indicates it was too wet to burn cleanly.

However, if you experience ongoing condensation in the tubes inside your house, there's something seriously wrong. A possible cause is that condensation created outside is able to drop down the pipe, then pass in through the wall. The horizontal pipe then needs adjustment so it drops slightly to the outside.

For Lasse Holmes, the inevitability of condensation and creosote are designed into the stove: "Cold start-ups run condensate. It's a cycle. It's like a distillation process in that it re-evaporates and can condense further down the line until the whole thing warms up to where it's not condensing anywhere. It is acidic and will eat up regular steel, can accumulate in chimneys and present a fire hazard, and can stain floors. When my exit temperatures run 180°F or higher, I'm not forming condensate; but when I get below that 180° point, I'm playing with the condensate. When we are pushing the limits of heat extraction close to the condensation point, we make sure to provide

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a stainless condensate drain at the exit AND use stainless for the Exit Flue. It's a trade-off, you can rescue ALL the heat and deal with condensate, or you can waste a little heat up the pipe but you don't have to deal with condensate. In Alaska it's worth it for us to have an insulated Exit Flue of triple-wall pipe."

Soot/creosote builds up in the exhaust pipe.
Creosote buildup is smoke condensing in your pipes. Smoke is unburned fuel, so look at ways you can burn wood more completely. Is the Manifold adequate, the gap at the top of the Heat Riser sufficient, is the Heat Riser tall enough (more than twice the Burn Tunnel length)? Are there any obstructions in the system?

I'm worried about cracking caused by metal parts in earthen stoves.
Any junction between dissimilar building materials creates stresses. In places where metal parts are in tight contact with cob, brickwork, or stone, heating and cooling create cyclic expansion/contraction of the cob.

A common example is a steel barrel heat exchanger enclosed or partially buried in cob or sand-clay. If at all possible, try to leave space for the metal's expansion or use flexible material in direct contact with the metal. Our friend Meka has experimented with using perlite-clay to buffer a wood-fired heating stove from the cob walls surrounding it. Another solution is to welcome the cracks, making allowance for them as is done in urban sidewalks by scoring the surface so cracking occurs in a predictable pattern. Make sure this scoring is superficial and the mortar is airtight around the barrel so gases can't escape and suffocate you. Another solution is to run the stove while building it, giving you instant feedback, offering the chance to change the position of parts before they dry in place, and also allowing them to settle into a margin of expansion-contraction ranges. If you set the barrel while it is still wet, when it contracts it will set an expansion and contraction joint automatically.

I'm having trouble getting a good draw.
Kirk Mobert offers this tip: "What is your outside stack length and what is the height of the house? In case the house is higher than the outside stack, which isn't insulated, this could be the source of your trouble. Even a relatively small opening somewhere in the uppermost region near the roof will result in the house becoming a better chimney than the Exit Flue. The situation should improve dramatically by lengthening the Exit Flue to a level well above the roof."

My Rocket Mass Heater oscillates; that is, it draws fine for a moment, then the draw reverses slightly as if it's changing direction, then it goes back to drawing correctly, then it chugs and sends smoke into the room again. What is the remedy?
This is possibly caused by gusty wind—breeze, even. The remedy is better draft. Blockage somewhere downstream of the Heat Riser is one possible cause of oscillation. The faster it oscillates, the bigger the blockage. Give the whole thing a good cleaning.

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Drawbacks of Rocket Mass Heaters

Nothing's perfect except, arguably, Nature herself. Human gadgetry always has a downside. In place of extravagant claims—"the woodstove you always wanted" (how do we know what you wanted?) or "this stove will solve all your heating problems" (it almost certainly won't)—we want to address here aspects of Rocket Mass Heaters that people have found difficult.

Stoking needs to happen quite often with a Rocket, whereas you can fill a big box stove with wet wood and smolder it overnight. With practice, good luck, and straight long dense wood, you can feed an 8-inch every 1–2 hours. You can't keep it alight and burning clean all night, so it needs to be lit fresh each day, and in a few cases, twice a day.

Long straight wood works better. What if your firewood supply is all curved, short, knotty, and branched? Well, self-feeding by gravity gets difficult, so you might need a different design of Feed Tube, horizontal perhaps, with a grate beneath and a closed door. We need more research from the knotty hardwood zone. (See Lasse Holmes's horizontal-feed design for Alaskan climates in Case Studies, page 100.)

It's too much work splitting wood. In practice, an 8-inch system won't take wood fatter than your knee. If you don't enjoy splitting firewood, or if your firewood is difficult to split, burn small roundwood or construction scraps, or design a bigger-diameter system. A 10-inch flue can have an 8" x 10" Feed Tube, and can take wood up to about 7 inches. A 12-inch system (which we haven't tried yet) can probably stand a 10" x 12" feed. Big diameter systems are more suited to big heat storage, long heat extraction tubes, and multiple flue pipes, for instance for floor heating, greenhouses, or industrial use. They create higher combustion temperatures, so they need more robust materials.

Key parts need frequent replacement. In the combustion chamber, temperatures are very high (up to 2000°F) and thermal stress is intense (that is, temperature changes are extreme), causing breakdown of materials from expansion and contraction. Also, the hottest spot constantly moves around as the fuel burns and settles. Steel parts in the Feed Tube or burn chamber disintegrate by slow combustion, and ceramic parts such as brick crack, spall, and crumble. The fastest damage is often in the bridge covering the Burn Tunnel and around the base of the Feed Tube where the Burn Tunnel begins. It would be useful to find a more durable material. Perhaps castable ceramic or cast iron would perform better. Some people have been experimenting with castable refractory materials, and with replaceable parts at the hottest spots of the stove, such as the first brick in the roof of the Burn Tunnel.

Ash cleanout is not always easy. Cross sectional sizes in the combustion area are fairly critical, so stove performance suffers from ash buildup. Easier cleanouts might solve the procrastination factor. My own process goes like this: (a) As I clean out ash, I tell myself, "Get it out quicker next time!" (b) I burn my stove quite a lot in cold weather. (c) Every few days I remember I need to clean out ash. Each time other priorities get in the way, or I can't be bothered to look for the cleanout tool, or last night's ash is still too hot to handle, or I loaned out my only metal bucket that I can safely load with hot ash or it's dark, or it's Thursday, or there's a letter R in the month. (d) My stove gets gradually harder to light. I blame everything except ash buildup, such as wet wood, bad luck, bad weather, my long-suffering wife, etc. (e) The stove occasionally smokes into my house. Remedy? Close the Feed Tube, shake the fuel down more often, anything but empty ash. (f) Finally, I give in, find tool and bucket, kneel on a

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cushion, and empty an almost clogged system. An 8-inch system can yield 2–3 gallons of ash. Time taken? About 10 minutes, including redistributing ash, and cleaning tools. (g) I tell myself, "Get to it quicker next time!"

I think you can see the remedies. First, have a ritual cleanout day, say every Sunday morning before lighting it, if necessary, put it on the calendar. Second, keep the cleanout tools and ash bucket together in an easily accessible place. Third, try to remember that most smoking or hard-to-start problems are caused by an obstruction, usually of ash.

Response time is slow. This is another major issue with the Rocket Mass Heater. If the house and bench get cold, it can take a while to heat them up again. In climates where heating needs are intermittent, the system works less efficiently.

Rocket Stoves need an attentive sophisticated operator. Rocket Stoves are an invitation to be involved. Choice of fuel is an art, both when selecting it and as you feed it piece by piece. Here's a stove that continuously reminds you of the diversity of Nature. If you screw up, fail to pay attention, or work too fast, the stove punishes you with smoking in your house or being hard to start. This is not a stove for people who rent their house, unless they have real interest in the process. It's also not so good for guest houses or situations with rapid turnover of residents. And finally, in just a few cases, they just plain don't work. Of conventional box stoves you could probably say that they *mostly* don't work, so don't be alarmed. We know of only three nonworking examples of Rocket Mass Heater. Two were built by neophytes whose symptoms were impossible to diagnose by phone, so perhaps we can discount that. But the third was a demonstration stove built at a workshop. How embarrassing! With every adjustment we conjured up to try, it still won't work well. It backdrafts, filling the whole house with smoke, and we can't figure out why. Don't let any of this discourage you. Now, hundreds of Rocket Mass Heaters are in operation, most without a glitch. We encourage you to take a hands-on workshop and to take advantage of the resources online (mentioned at the back of this book).

The fire is difficult to see. If you're used to the visual magic of armchair fire gazing, you may find it disappointing. You can however watch it from above, and there's the compensation of *listening*. Rocket Stoves are an audial feast. Burning strongly, they can roar like a little rocket, and the intense temperatures snap and crackle the firewood. Subtler is the gentle thud every so often as a piece falls down the Feed Tube, when you hear the burn respond immediately. We've heard reports that this sound was what people liked best of all. "It's instructive. I can attend to it by sound prompts."

Conversely, the thuds and shufflings remind your subconscious that the stove still has fuel. When they stop, you will gradually notice it. As with little kids in another room, it's when they go quiet that you have to check them out. As long as there's noise, everything is okay.

Do you really need to see the fire from your couch? Turn off the lights and watch dancing patterns on the ceiling.

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Fire! Fire!

—Art Ludwig

Among all phenomena, it is really the only one to which there can be so definitely attributed the opposing values of good and evil. It shines in Paradise. It burns in Hell. It is gentleness and torture. It is cookery and apocalypse.
—*Gaston Bachelard,* The Psychoanalysis of Fire

If you have a wood-burning device, there is a fire burning in your home. In this chapter, Art Ludwig (from wildfire-torn Santa Barbara, California) joins us to caution you on some of the dangers. Most accidental fires arise not from one spectacular failure but from the interaction between multiple small failures and oversights, such as improper use by guests plus gradual buildup of creosote in the chimney. As these stoves move from "the dabster zone" toward more common usage, we feel compelled to expand on prevention for laypeople and pyrotechnologists alike. Art hopes this section will not discourage you from installing a Rocket Mass Heater but will encourage you to use one safely (and encourage your neighbors and friends to get a bit safer as well). We advise you to read this section carefully. *(See also Art's case study, page 104.)*

Of the top historic hazards attributable to the built environment—waterborne disease, structural collapse, and structure fire—structure fire is the one that still kills a lot of people. Deaths in the United States are about 7 per million per year from structure fires, compared to 0.02 for structural collapse and 0.01 for waterborne disease.

Mortality in houses with woodstoves is probably much higher than in those without. A safe installation is not easily arrived at from common sense alone. Woodstove installation is a case where the building code offers truly useful guidance. Still, fires occur seldom enough that complacency and denial can easily take hold. Most of us do know people whose houses have burned down from woodstove-caused fires. In my view the biggest hazard of Rocket Stoves is that builders tend to have a negligent attitude toward fire safety codes. I'd encourage people to look at each line in the code on its own merits and not throw the whole thing out. It addresses issues that casual builders cannot anticipate because they are outside common experience: we may not have been there for 30 years to see the wood pyrolyze, for example, we can't conceive of someone using the system in the most foolish ways possible; and most of us have never seen a flue fire. The code blankets every scenario for every kind of builder and operator. That's something it's good at.

Earthen buildings are inherently more firesafe. Look at the whole picture, including climate and cancer, and they are WAY more safe. If you can make the woodstove installation and the rest of the fire safety measures impeccable, it paves the way to converting building officials to Natural Building believers on grounds of personal and public safety.

Just last week I saw an otherwise competent woodsman, while drunk, come within minutes of burning down a house with four people in it. He had the doors of the stove open, the air intake and damper open wide, and the stove generously loaded. It was his home, not mine, and I didn't know he was also generously loaded—so when he told me not to worry, I turned to leave, but he left first, singing his way down the stairs. Just then the fire popped sparks over the rug. I closed the stove door and turned the damper down, then discovered that the newspaper hanging by the stove was about to catch fire. A few minutes later the firewood drying behind the stove caught fire, but I was able to pick it up and throw it out the door. Three ways the place almost caught fire: sparks, newspaper, and stored wood.

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★ What is hanging above, sitting around, or leaning against the stove? The neighborhood of the stove can easily get cluttered with things such as drying wood, matches, and food items like olive oil. Don't leave anything flammable dangerously near or touching the Heat Exchange Barrel or the Feed Tube, nor in a place where it could possibly fall onto the top of the stove. Overhead shelves, drying firewood, wet clothes, towels, kindling, anything plastic or wax or wood or paper could all start a fire when you're not looking, or produce toxic gas while you're asleep. If a hot part of the cob is reading only 200°F when bare (exposed), a backpack leaning against and insulating it could get up to 500°F. Leave a good wide space around the stove without carpet or anything else that could catch fire.

★ A major hazard specific to Rocket Mass Heaters is the delay for heat to get to the bench surface. If it takes 2 hours for the heat to reach the surface, it's all too easy to just keep stoking. The first 2 hours the bench goes from cold to deliciously warm, then the next 2 to pillow ignition temperature. Because heat moves through the pipeline for hours, pillow-ignition could happen when the fire has died down completely, the lid is on tight, and people are gone or asleep.

★ Install and maintain smoke/CO detectors! These are the low fruit of fire death prevention. I've spent a lot of time persuading building officials to think more like natural builders, but the wisdom exchange goes both ways. They just shake their heads about people who don't want smoke detectors. And it is kind of hard to come up with a persuasive argument against something that is so cheap and effective for saving lives. Until Rocket Mass Heater dynamics are very well understood, a CO detector is also a very sensible precaution. We moved ours all around the room under varying conditions and never found CO. Now we don't worry about it so much…but we still have it by the bed.

★ Don't go to bed with a dragon. In gusty weather, make sure the wind doesn't cause gases to back up through the Feed Tube. One windy night, Leslie was meditating in Kirk's mud hut and the fire became suddenly quiet. She looked over, and it had changed directions, sending a dragon-tongue of flame into the hut. Stop stoking a couple of hours before you go to sleep; once you make sure the coals have died down, then put the lid onto the Feed Tube as tight as possible. (Kirk has since fixed this tendency with a rotating cowl.)

★ Resist the temptation to burn long fuel: the odds of back-drafting are too high. If you are burning long fuel, don't leave it unattended. It may snag up and fail to feed by gravity. Then it can burn up to the top of the Feed Tube and fall over because it's top-heavy. Also, two long pieces of wood can form a chimney column between them that backdrafts. Make sure any long pieces of wood burn down before you leave the area.

★ Ceilings over Feed Tubes should be noncombustible or high above the stove. This reduces the hazard of fire from backdrafting. A nice touch is to make this a light-colored surface that

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reflects the play of firelight over the whole room. I installed cement board—with an air-gap to allow a duster in—and painted it over with white *alis* (clay paint) containing flecks of shiny mica. The added pleasure of watching the reflections of the fire dance on the ceiling make this safety feature worthwhile on aesthetic grounds alone.

A section of Duravent® Class A Triple-Wall Pipe. Air chamber circulates cool air through the chimney to help keep the outside of the chimney cool, if a chimney should have a creosote fire.

★ Especially if the vertical stack is exposed inside your house, or you have a very long horizontal flue, be sure all the joints are airtight so combustion gases can't seep out into your house. **Under no condition** should you install a chimney damper; it will constitute a bottleneck that could back up toxic gases such as CO.

★ Don't let any smoke get into your living spaces. Even tiny amounts are bad for you. If the stove ever smokes, open all the doors and windows. Don't repeat whatever it was that caused it.

★ **Slow Changes in materials.** Exposure of wood and other materials to heat over time can lower their spontaneous ignition temperature. Above a wooden floor or close to a wall, keep a gap, remembering that sheetrock-gypsum board transfers heat well and nearly always has wood behind it. Counterintuitive physics warning: In confined spaces, insulation slows but does not stop the attainment of high temperatures. While insulation slows the attainment of maximum temperature, the steady-state maximum temperature will not be lowered by insulation alone(!).

★ Only removing heat from the space by airflow, water-flow, radiation, etc. lowers the steady-state maximum temperatures in the materials.

★ Triple-wall stovepipe, for example, uses lightweight insulation to slow heating, and then vents the exterior space out, so the heat that makes it through the insulation can escape. If you block these vents, the temperature of the outside of the pipe can reach close to the inside of the flue!!!

★ Even people who are used to metal woodstoves don't necessarily realize that clay can get hot enough to catch a jacket, backpack, or kindling on fire. Due to its low conductivity, clay might even feel okay to the touch. However, once insulated (say, by a jacket set on it to dry out), it can heat up dramatically.

★ Wet wood burns badly and gives off substances which may condense to leave increased creosote in your system. Firewood needs to be dry, as dry as possible.

★ Design for a long run of duct through the heat storage: more than 20 feet total, if possible. Short runs of duct do not allow the mass to absorb as much heat as you would wish. Your exit temperature could be dangerously and inefficiently high. Aim for 100–150°F or lower.

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★ If you employ painted or galvanized metal parts in the Combustion Unit, burn off the coating before installation, out-of-doors, and remember the fumes can be deadly.

★ Be careful where you burn a Pocket Rocket. These are varsity-level hazards that require constant diligent attention. They can get extremely hot. Even a 5-gallon model can radiate at such a high temperature that it can ignite paper several feet away. Site an indoor Pocket Rocket very carefully. Protect children (and pets) from the metal surface, which can reach over 1000°F.

★ As the stove builder, you are an inherent part of fire safety. You are familiar with its potentials and it is second nature to you to check for what's (to you) the obvious. But what if someone else is operating your stove? It's generally not the builders who burn the house down. It's their guests, their renters, or their renter's guests, especially people who don't know much about wood burning. Friends of ours in Northern California had their city guests load the firebox with an entire box of pencil-sized pieces of pitch pine—a month's worth of kindling—then leave the cabin with the damper wide open to get more firewood. Minutes later when they turned back from the woodshed, the whole interior was already on fire.

★ Pillow ignition. Know the surface temperatures of various parts of your bench after a very long burn and beneath any cushions, mattress, etc. An ambitious Rocket Stover (we won't mention names) recently set his bedding on fire. Choose cotton and wool. DO NOT use bedding that contains fire retardants. Add insulant plaster to the bench parts that get dangerously hot, and know how long it takes to get it just right. I have a tile sign on my stove that reads, "Do not fire for more than 3 hours continuously."

Record the surface temperatures of various parts of the stove and bench.

Illustration: Leslie Jackson

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★ The building code for woodstove and stovepipe installation seems—and is—ludicrously overkill for normal use. Normal use is not what the code is for. It is to avoid loss of home or life in unforeseen conditions. However misguided other parts of the building code may or may not be, the stovepipe standards are generally well-informed and worth following. If you deviate substantially, be sure you understand the physics of what you're doing; the payoff is worth it. We don't yet know the risk Rocket Mass Heaters are for flue fires, long-term. $300 extra worth of triple-wall stainless steel stovepipe on the roof—an incredibly conspicuous location for any change to a house—may be of little fire safety benefit, but it broadcasts a reassuring signal to neighbors and passing inspectors: "no fire hazard here." Yes, in theory you could have a whole long conversation about how low-temp Rocket Stove exhaust is, but this won't be an easy sell for savvy inspectors; they know that the triple walls are not necessary for decades of normal use, they are for that one flue fire in 50 years. I don't believe anyone has hard data to prove that Rocket Mass Heaters will never create conditions for a flue fire—even if just once a century, that's still worth the $300.

★ Residential sprinklers are not cheap, but they are effective for saving lives. They are also very effective for calming fire authorities, who may then be inclined to be more flexible about, say, waiving the requirement to double the width of your half-mile-long access road.

★ Alternative fire escape paths are another sensible part of the code and well worth it even if used once in 100 years.

★ All stovepipe runs should be cleanable.

★ Hydrants, fire extinguishers, and hoses are the last line of defense to put out a fully engaged structure and/or keep a fire from spreading. If you are building without permits, rather than going for no hydrants, consider going for small, numerous hydrants with 1-inch diameter hoses. These are easy for one person to use quickly to get to a fire while still small. Although they don't have the flow of a bigger hose, they can offer four times the flow and throw of an average garden hose.

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We have given you a very specific recipe for making one particular model of one size of one kind of Rocket Mass Heater. This is like a recipe for chocolate chip ginger saffron cookies with 143 grams of butter, 212 grams of flour, 96.7 grams of honey, and exactly a quarter of a pinch of salt. In other words, we've tried to faithfully give you the instructions to build one stove that we *know* works well.

Now you're wondering how much flexibility there is in the measurements, proportions or materials. Already I can hear you asking, "But what if…?" "What if I don't have any mason's sand? Or if I can only find 7-inch pipe? What if your stove doesn't fit into my house? What would happen if I wanted the bench higher? Can I heat my walls or floor, or build a stove for a completely different use such as heating a workshop? Or a teepee? An ice-cream parlor?"

When we change one variable, it changes everything else, so you want to know the significance of changes you may make. As with many aspects of physics, a linear scale-down of dimensions is not normally followed by the same scale-down in area or volume. A fire twice the size doesn't do everything twice as much as one that is half the size. But we can make some predictions about how well size variations will probably work and from experience we can warn you about some things that definitely do not. For example:

• A system smaller than 6 inches gives much-reduced power output, and needs much more frequent stoking, cleaning, etc. A smaller barrel gets a lot hotter to the touch, radiates a lot more heat, and is more dangerous.

•Any blockage or narrowing downstream of the Burn Tunnel reduces draft.

• A very long Burn Tunnel loses power.

• A metal pipe for the Heat Riser burns out very quickly.

Start by consulting Dimentia & Proportia, page 28. Almost certainly, if you choose to make the Heat Riser higher the stove may burn faster, whereas if you choose to make the exhaust pipe higher it will have very little effect. If you make the Heat Riser shorter you will come to a point where it doesn't work at all, but we can't tell you exactly where. You have to try it. The longest heat storage flue we have seen is over 30 feet and performs excellently, so we can guess that a 55-gallon barrel with an 8-inch flue can push hot gases 40, 50, probably 60 feet. Beyond that is mere speculation.

We also know that heat is lost more rapidly from hot objects than cooler ones, so the most critical parts to insulate are the surroundings of the Burn Tunnel and Heat Riser. The stove we describe in detail heats people in a small house in a fairly mild winter climate quite effectively. For a bigger house or a colder climate (or colder people) you might try to scale up the whole unit, giving the entire digestive tract a bigger cross-sectional area and making the Heat Riser taller. Try a 10-inch-diameter flue.

For heating a greenhouse, you can run your exhaust pipes through the floor to maximize the amount of heat storage by placing them low in the building. Ernie Wisner suggests, "The raised bed is probably the best, as it gives you a nice thermal mass and plantings at a workable height." But with a greenhouse stove, moisture is always present and you are advised to build with flues that won't rust, using for instance brick, stainless steel, or aluminum.

Can I heat water with it? It's a really popular question, as Kirk Mobert will tell you from moderating the online forum for 10 years. It has an unfortunately complex, slightly disappointing answer. "Heating water in an open container such as a pot or open tank is fine. But if you incorporate a heat-exchanger coil, things get complicated and even dangerous quite quickly.

"If you plan to heat water in a pressurized system, know what you are doing or you risk your life and/or the lives of your family and friends. When water turns into steam, it expands over a thousand times its original volume! This rapid expansion can lead to rupture and/or explosion of heat exchanger tanks, coils, etc. Steam explosions are VERY powerful—boilers have been known to level apartment blocks—and short of explosion, a rupture can spray super-heated steam, which is invisible and deadly."

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Depending on how you rank the distinguishing features of a Rocket Stove, some of the following examples of other kinds of Rocket Mass Heaters could be seen as Something Else. They have some Rocket characteristics, but not all. (Some may lack heat storage, so although they burn extremely clean, they do so at the cost of wasting heat up the stack. We thought it useful to include them as they may stimulate further tinkering and teach us other aspects of wood-burning technology.) To help design your own mass heater to suit your needs, we highly recommend building a few of these as experiments toward understanding principles which you can apply to your own imaginative tinkering.

Detroitus & the Pocket Rocket:

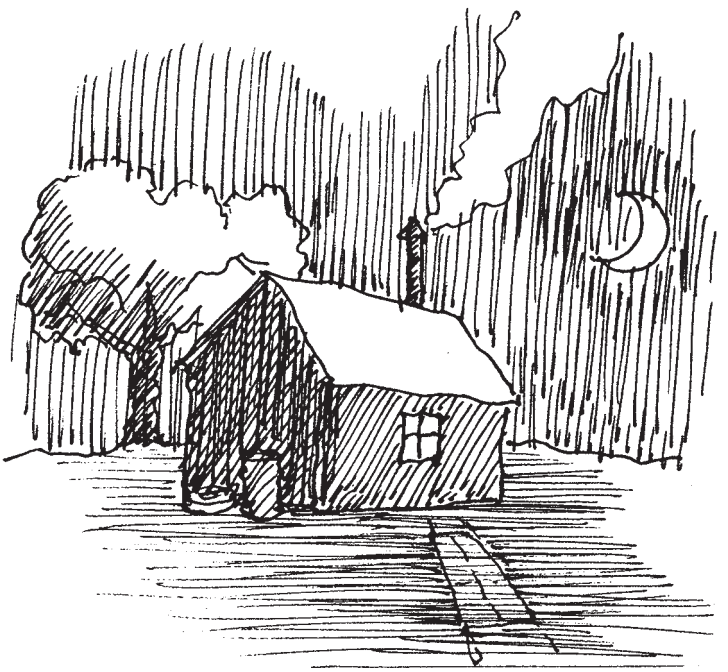
Ianto stumbles upon a can stove

Shortly after Larry and Sandy Jacobs bought their farm, and long before they built the house there, he and I were working all day in the rain. There was no shelter, it was midwinter, and we got soaked and chilled. As darkness came on, we packed our tools and drove back to the pickers' shack Larry and Sandy had rented on another place. Just the time for a hot shower and a mug of cocoa in front of a blazing fire!

We had the cocoa, but there was no woodstove or shower in the shack and no easy way to warm up. California farmers clearly felt little need at that time to provide comfort for their seasonal workers. We were blue with cold; the cocoa didn't help that much. Finally we switched on the gas stove and sat with our feet in the oven. After a while, Larry looked at me and laughed. "This is ironic," he said. "Two of the world's experts on improved stoves sitting with their feet in a gas oven. Why don't we build a woodstove?" So we bundled up and went back out into the pouring rain with a flashlight.

Like many California farms, the place was rich with junk piles—"Detroitus," as David Eisenberg calls it.

We found a 55-gallon barrel and assorted lengths of rusty stovepipe and took them back with the vague notion, I suppose, that we could build a barrel stove by banging a door into one end of the barrel, laying it flat and poking a flue into the other end. But somehow we screwed up. The frigidity of the night must have affected our brains. Both holes ended up at the same end of the barrel. So we stood it upright, connected



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the flue to one hole, and poured burning kindling down the other. It took off instantly, roaring loudly. Little did we know we had invented the Pocket Rocket. But then we didn't care much; it was just too comfy, slowly rotating our steaming bodies and sipping hot cocoa.

The stove that Larry and I made was a Rocket Mass Heater ancestor. How Pocket Rockets work has to do with the fuel and the incoming air both being preheated because the Feed Tube is actually inside the burn chamber. Both stoves are similar in that there is an abrupt 180-degree bend at the bottom of the Feed Tube, there is gravity feed, and the feed chamber is separate from combustion. Also, the high temperature of the stack drags in fresh air at high velocity.

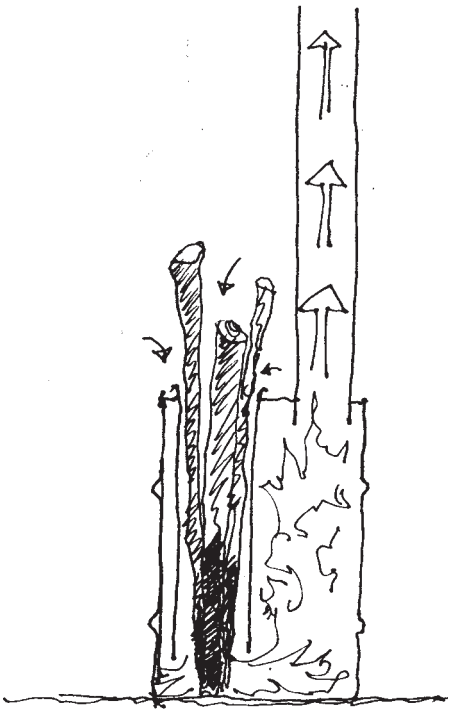
Pocket Rockets waste a lot of heat up the stack, so it's good to use a small-diameter pipe. But they are incomparable for delivering foot-level radiant heat quickly, even outdoors in the worst weather.

Our dream was that their construction could be taught to homeless people to get fast heat on windy street corners by burning scrap lumber out of dumpsters.

We later played with the idea at an alternative kids' school in England, scaling it down to as small as a 3-quart paint can with a bean can for a feed and a 2-inch downspout for the stack. More recently, Tracy Johnson made a truly pocket-size one with a beer can and two pieces of 1-inch steel pipe. "Hard to keep it going though," she says.

We taught workshops to suburban housewives on how to make a 5-gallon Pocket Rocket with a tire iron and a rock in about 25 minutes if you're stuck at the side of a road near a landfill.

Note that the greatest heat output is from the *bottom* of the Pocket Rocket, and it can get alarmingly hot. We have seen them cherry red all-round and hot enough for the can to buckle up like a concertina: a dangerous source of heat radiation that can ignite flammable objects at 2- and 3-feet distance. Be sure to keep the kindling, paper, furniture, etc. at least 3 feet away or surround your Pocket Rocket with a safety wall of brick, cob, or polished aluminum.



Pocket Rocket

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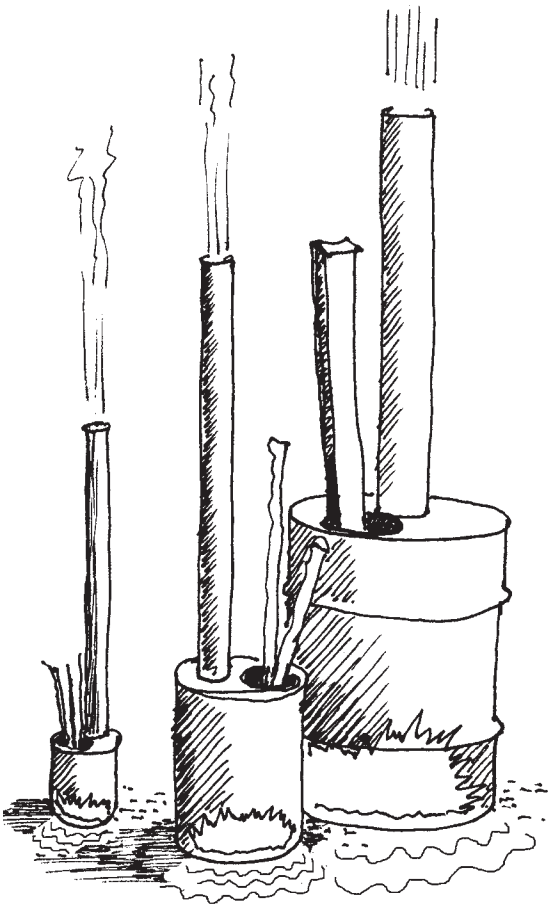
How to Make a Pocket Rocket



Here's what later developed from the Larry Jacobs stove (see page 81).

Pocket Rockets come in many shapes, sizes, and styles. The type pictured is an outdoor radiant heater. It's made from cheap materials that are often found in the waste stream. Because of its tall chimney, it has a relatively clean burn, but of course what heat isn't absorbed by a human directly off the radiant barrel is sent to the heavens. The emissions are low though, making it a nice way to get warm around a fire in the city, for example. It requires very little wood to operate. It is also easy to make.

This recipe is for a Pocket Rocket with a 5-gallon burn chamber (using a 5-gallon can or pail). It's possible to make one in any size. The pipe sizes will be proportional. For example, a 25-gallon drum works well with an 8" x 25" Feed Tube and a 4" x 66" flue pipe. These measurements are fudge-able. It's the proportions that matter.

MATERIALS

5-gallon metal can or pail with removable lid, cleaned of finish paint or residue
3- or 4-inch diameter x 40–60 inch pipe (preferably not galvanized)
5- or 6-inch x 12-inch-long pipe (flat black stovepipe is preferred for both)
Newspaper
Firewood (dry, thin, straight, long)
Plenty of tiny kindling

TOOLS

Tin snips
Hammer and nail
Pliers
Felt-tip marker

SAFETY GEAR

Leather gloves (sharp edges are dangerous)

Construction. Remove the residues of paint and the pail's contents (see "A note on safety," below). Remove the rubber gasket, if there is one, from the inside of the lid. No lid? Turn the can upside down, cut into the solid end. The Feed Tube and the flue pipe are both attached at the same end of the burn chamber (the can or pail) in the lid. Trace the outline of the two pipes onto the lid with a felt marker (or nail, etc), placing each pipe toward the outer rim of the lid so there is plenty of material left in the lid itself to support the pipes (see illustration). To create a tight fit for the pipes, draw a circle inside each original one that is an inch smaller all-around.

Bang the hole in the center with a hammer and nail, chisel, or other sharp object. Then from the starter hole, use tin snips to cut out the inner hole. An easy way to do this is to cut in a spiral pattern from the middle out to the inner marker line. Do

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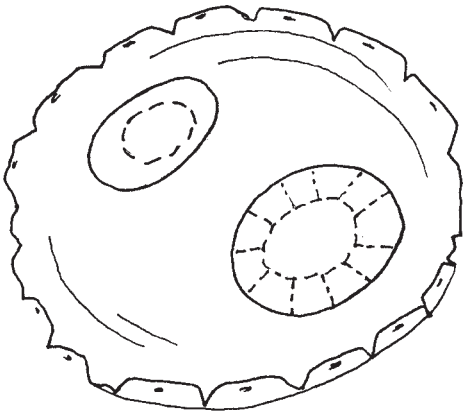
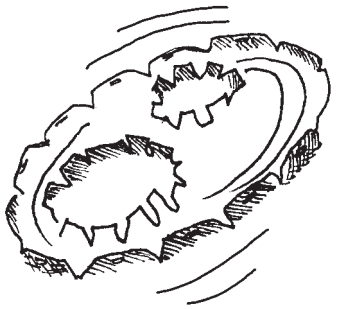


The flip-side of a can lid with large and small pipes traced onto it

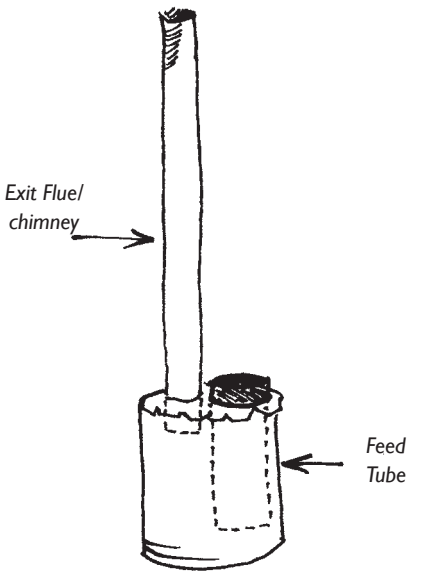
the same for the other hole. Now you have a can lid with two holes which are both too small to accommodate the pipes. Using tin snips, cut tabs about half an inch wide, radially from the hole's center out almost to the pipe's actual line. These tabs will hold the pipes in firm and tight and allow more control and adjustment when fitting them. Using pliers, fold the tabs almost to right angles pointing into the can. Now you have a dangerous Frisbee.

The shorter wider pipe, which is the Feed Tube,



Can lid with tabs cut out and folded back

hangs inside the can, almost to the bottom (see illustration). The long Exit Flue pipe sits into the can only a few inches, just enough to hold it steady. Put the lid on the pail or can and friction-fit the two pipes into position, making adjustments to the tabs as necessary for a nice tight fit.



Illustrations: Leslie Jackson

Operation. Light the corner of a piece of crumpled newspaper and push it down the Feed Tube and under the flue. Or drop it, burning well, down the chimney. Flames should be drawing up the flue pipe. Slowly feed more burning newspaper to burn at the bottom of the Feed Tube. Add more paper, then a few pieces of very thin long kindling, standing upright in the Feed Tube. The object is to keep the draft going in the same direction: into the flue. Add more fuel into the flame path. You can regulate airflow into the stove with a piece of sheet metal, a brick, or a tile a little larger than the pipe. There are many ways to enhance the burn quality. Experiment!

A note on safety. A lot of the pipe out there is galvanized (zinc coated). Galvanizing melts at 787˚F, but it offgases at a lower temperature than that. We like to avoid galvanized pipe.

Most steel pails are painted (to keep them from rusting). This paint must be removed, using coarse sandpaper or an electric angle grinder, finishing the job in a small bonfire. Who is downwind (including you)? Wear robust leather gloves, and *stay out of the smoke.*

Purchased by Johnathan Yelenick, johnathan.yelenick@gmail.com #11023292

The Guatemalan Cookstove: Estufa Rocky

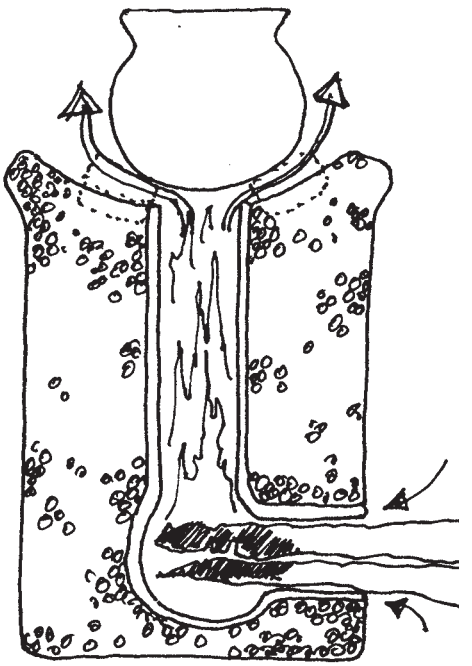
In the late 80s Ianto's work as a trainer for the Peace Corps caught the attention of the Guatemalan Minister of Agriculture, who thought a clean-burning wood fired cookstove for the urban populations, especially in Guatemala City, could reduce the devastating deforestation happening all around the capital. At that time, more than a million people did their daily cooking on little open campfires inside their homes, particularly the recent settlers in the huge squatments that filled the steep ravines surrounding the more formal parts of town. Daily, huge trucks brought massive loads of pine firewood in from the mountains. It was sold in street markets and corner stores at a substantial price. Families were spending up to a third of their meager incomes on cooking fuel. For some people the choice was to cook or to buy food; they couldn't afford to do both. As with anything the government wants, everything had to happen quickly, so suddenly there was a staff of five, a lab in Guatemala City, and 12 days to come up with a stove that would cut firewood use in half.

The device we developed cut fuel use by more than 50% and was the fastest-cooking stove of the hundreds we tested in those years. Its core was a terra-cotta elbow 4 inches in diameter, which created a Heat Riser about 20 inches tall and a horizontal Feed Tube about 10 inches long. The elbow was cast into a lightweight pumice-concrete cylinder, and cooking happened on top of the Heat Riser. We made no attempt to get the small amounts of smoke it produced out of the house. With a budget of US$4 per stove retail, there was little room for refinements.

The Minister of Agriculture, delighted by the results but a pragmatic realist, said, "What do you mean 'Rocket Stove?' That sort of title will never fly in Guatemala. We will call it *Estufa Rocky!*" ("Rocky" was the name of a series of movies which were very popular in Guatemala at the time.)

In cooperation with an existing concrete castings business, we had a hundred cast initially. They were put out "on loan" to families, for a month. Then we went back and pretended we were going to take their stove away and counted how many said they would pay $4 to keep their stove. More than three-quarters paid up.

Most of the users loved these stoves—not so much for their firewood savings (who counts firewood anyway, unless you have a scale and a laboratory?) but because they cook really fast. It is a marvel to busy people who normally cook on an open fire to be able to keep the fire going with only one stick, and serve meals rapidly.



Estufa Rocky

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The Coffee Rocket

In the office of our Danish partner, Flemming Abrahamsson, among the stylish Scandinavian furniture and beautifully drawn plans, sits a little fireproof fiberboard box recessed into the surface of the desk. When clients come to discuss the architecture of their buildings, Flemming asks, "Would you like some coffee?" He puts the coffeepot on top of the box and sticks a match in its mouth. His Coffee Rocket boils 1 liter of water in 4 minutes, easily outdoing gas or electricity, and produces so little smoke that it has no need for a chimney. It's made of low-density high-temperature mineral fiberboard, which you can buy by the sheet and cut with a handsaw.

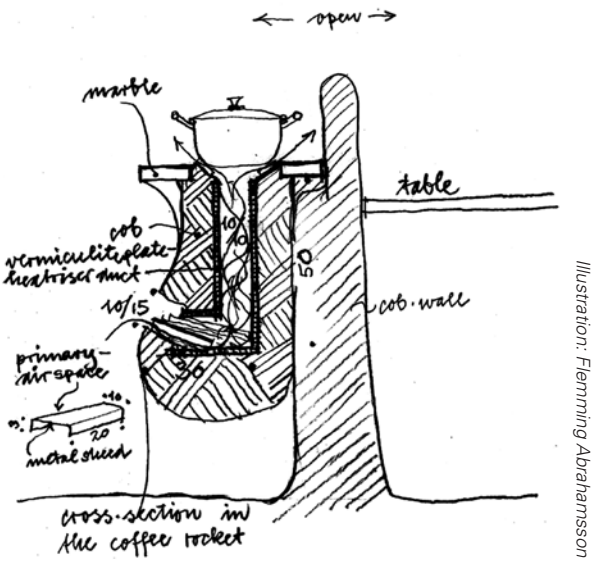
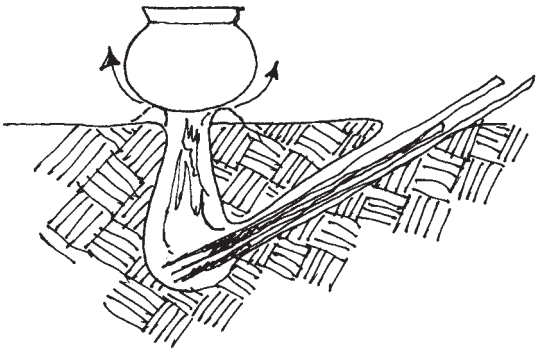


Illustration: Flemming Abrahamsson

Dimensions are in centimeters.

The Bengali Pit Stove

In the heavily populated delta of the Brahmaputra, rural people lack many resources and are desperately short of cooking fuel. Long before Rocket Stoves were around, the people there developed underground stoves using similar principles. Combustion happens in a flask-shaped pit about a foot-and-a half deep. The fire is fed with tiny sticks and pieces of agricultural waste through a diagonal tunnel, which intersects the bottom of the pit (see diagram). Dry soil is quite a good insulant, so the burn is very hot. The cook pot is perched on three little clay hills equally spaced around the rim of the pit.



The Bengali Pit Stove

These stoves are extremely efficient in the amount of fuel used and the speed with which they cook, and they have a great advantage over fires or stoves above ground. They almost eliminate heat lost to wind, as well as the cook's discomfort from waste heat radiating from a cooking fire in a very hot climate. Nearly all of the pit stove's heat goes into the pot.

You might try this one next time you go camping, or even in your backyard. The investment is minimal and the rewards are high.

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Research Needed & Experiments

Since earlier editions were published, considerable experimental work has been done, all by amateurs, some of it with surprising results. Thanks to the online forums (and there are many, including one in French!), we have learned about ways to improve draft and ways to improve combustion. This remains an exciting field, wide open for low-cost research by anyone with a little time and creativity. We are happy to put researchers in touch with one another and to help new builders find local workshops. Find updates and more discussion at www.rocketstoves.com.

So far, most Rocket Mass Heaters have been built with 6-inch- or 8-inch-diameter exhaust pipes. Experiments with **bigger stoves** with **bigger power outputs** would be interesting. They might necessitate more durable high-temperature materials for the combustion zone, such as castable ceramic, fireclay-fiber mixes, or fireclay-insulant mixes.

How far horizontally can a Rocket Stove push hot gases? Our own greenhouse stove works well with 36 feet of Exhaust Flue and no vertical stack. What would it take to heat 60–100 feet to push exhaust downward several feet?

Hypocausts means underfloor heating by hot gas. They were used 2000 years ago in the chilly British Isles by the Romans. Normally they used sandstone slabs for the floor, suspended on sandstone pillars 2 or 3 feet high. Now that underfloor "radiant" (hot water or electrical) heating is popular, this may be something useful to explore.

Less work in splitting firewood and less frequent attention are desirable. Ways of creating a bigger feed chamber would help a lot.

How about a Rocket Mass Heater that runs on **clean construction waste and forest thinnings?** If your access to burnable fuel is from forest restoration thinnings, or from the cut-offs from carpentry projects, what would your Rocket Stove look like? Many people find themselves in this position, wanting to reduce flammable materials in their forests or to rescue fuel from the waste stream.

A foolproof self-loader to guide fuel into the Feed Tube could help with the use of longer wood or very short wood such as wood chips, pellets, or sawdust, and should protect from burning pieces falling out of the stove.

What about a Rocket with the fuel loaded vertically in a closed loading stack, with the **air inlet on the side at the bottom** of the Feed Tube? It might be that you could expose the air vent as a very small window of very hot fire visible in the room, heating the feet by direct radiation. For chunky or curved fuel, would a horizontal loader be worthwhile? What disadvantages would it have? (Lasse Holmes has been building horizontal-feed stoves for the Alaskan climate. See his case study, page 100.)

Pre-cast pre-assembled kits make building these stoves more accessible to more people.

Home-made fireproof insulants, e.g. clay-sawdust, clay-wood chips, clay-paper fiber, etc.

Saunas and sweat lodges could well be Rocket powered. There is a lot of interest in this. (See Kirk Mobert's case study, page 94.)

A submersible Rocket Stove for heating hot tubs? In the 1980s, an enterprising inventor in a physics laboratory at the University of Alaska came up with a welded marine-grade aluminum woodstove called the Snorkel, specifically designed to heat a wooden

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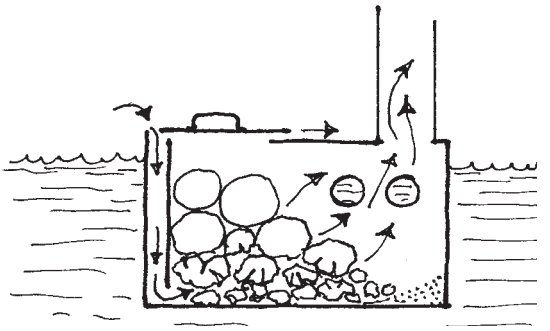
hot tub. It had some similarities to the Rocket but the fire chamber was not separated from the heat storage, so the combustion temperature, was too low for a clean burn, and a great deal of heat was lost up the stack. Someone inventive should be able to improve on that.



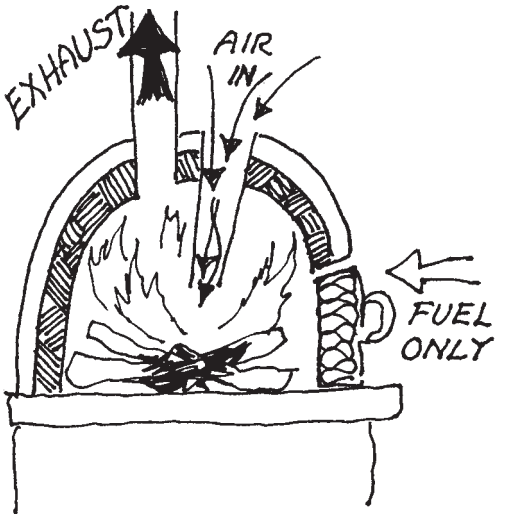
The basic Snorkel concept

Better Pocket Rockets. More durable feed pipe, safer surfaces, less stack heat loss, their use as cookstoves—all are promising, as is a wider range of applications. For instance, can a Pocket Rocket be a mass heater? Or, how else could we store the heat produced?

Radiant floor. This Rocket Mass Heater application crosses everyone's mind as they begin to understand the possibilities. For floors, many people are looking to send water through in-floor water lines, rather than an 8-inch flue of stove exhaust, to take less space. Regarding the through-the-floor-exhaust-pipe model, Kirk Mobert advises, "One issue with in-floor piping is: how to plan for cleanouts. At some point you will probably need to vacuum out ash buildup from some inconvenient corner."

Beehive ovens normally bake really well but burn really dirty. Shortage of oxygen and low surrounding temperature, coupled with no effective chimney, are a bad combination for clean burning. A little experimental work by Jim and Tyra Arraj hints at possibilities for a better bread oven with cleaner burn, greater efficiency, and fewer neighbors calling out the fire truck.

The Arrajes installed a short removable chimney, which creates suction that hurtles preheated air down the downdraft pipe onto the fuel. The oven door is kept closed except when adding fuel.



Flip and Jon Anderson built an excellent example with a slideshow to accompany it. Go to www.handprintpress.com/authors/kiko/new-rocket-oven-design-by-flip-and-john/.

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Case Studies

In 2003 after one of his excellent fire demonstrations at a Natural Building Colloquium, Ianto asked for a volunteer to "type up his notes" on this subject. My hand shot up, and before I could yank it back down I had committed myself to an adventure I don't think either of us knew this little book would become. We spent 2 weeks together on the warm bench at Ianto and Linda's Heart House, and Ianto dictated the book. Ten years later it's really remarkable that this stove not only caught on in Oregon in cob buildings but also in Japan, Australia, throughout Europe and the internet and in all kinds of buildings, with all kinds of adaptations. Some people building Rocket Mass Heaters have never even heard of this book. But more remarkable to me is that in spite of the many innovations others are experimenting with, the simple $100 stove described in the First Edition is still the one this book is about. Ianto has lived with it for 25 years. "Why," he asks in his precise Welsh accent, "improve on perfection?"

Compiling these Case Studies has been an adventure, beginning with a visit to Alaska in late March to the off-grid home of Lasse Holmes, who kept this Californian alive and fascinated. Using dogsled, snowshoe, and even climbing ropes to get from the road to his cozy home, I got to experience first-hand the real need for heat, and the real comfort of a well-built Rocket Mass Heater. Then at an opposite extreme, Art Ludwig and I wrote both his case study and Fire! Fire! chapter hip-to-hip in his hammock in Santa Barbara after a night of drumming on the beach under a full moon.

By publishing *Rocket Stoves to Heat Cob Buildings* in 2004, Ianto and I invited many inventive tinkerers to play in the context of their own conditions, climates, and materials. Some are casting their own "high-test" bricks, for example, and others achieving 100% combustion under tight laboratory-like circumstances. There have been so many innovations in fact, that the basic model in this book is now called "the Evans." (Sounds like a dance move.) Here you can find out about the Holmes, the Donkey, and the Peterberg, too. They're built by a hand-picked group of folks, most of whom Ianto directly taught. Some of these stoves stray pretty far from the original recipe we provide, and others stick to it and are perfectly satisfying. We know that even those stovers who stray from the recipe have already built the recipe model and applied the dictates of their conditions, climates, and materials. They know the major risks and they build heaters, not hot-rods. Most of them live with their Rocket Mass Heater and many have for several years.

—Leslie Jackson

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ERNIE & ERICA WISNER. *Ernie was on the research team for the Second Edition. Now he and his wife Erica are helping make "Rocket Mass Heater" a household term. They teach workshops all over North America, and sell plans as well as their books* The Builders' Guide *and* Art of Fire. *In their eighth year of Rocketry together, they have built, supervised, or fixed installations in a wide variety of buildings. They have advised on all six inhabited continents and on devices including a tropical hardwood kiln, coal-fired cooking and heating stoves for Mongolian families, and larger heaters for schools and community buildings.*

Find Ernie and Erica at: www.ernieanderica.info.

Photo: Calen Kennett

We built our own heater for our 800-square-foot cottage. This is an alpine year-round residence. Elevation is 3500 feet (1100 meters) above sea level, on the first mountain south of Canada in central Washington. Snow stays on the ground from October through April, with winter low temperatures dipping into the negative teens and twenties Fahrenheit (-10 to -30°C).

The building is a converted garage with a two-room addition, all stick-framed walls. We have reasonably good insulation (R24 to R36) with reasonable sun exposure and wind shelter.

Our 8" heater fits substantial thermal mass into a small space (see image below). We had 4 by 9 feet available between two doorways on the original floor slab. (Locating the heater against an interior

Photo: Erica Wisner

A barrel clamp connects the full-size barrel to a partial barrel. The lower barrel is enclosed in masonry and cob.

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wall helps even out the temperature between two rooms.) The heater is 3 by 9 feet with a back about 4 feet tall. We ran the chimney through the interior wall and then out through the roof of the addition. The chimney warms the back room nicely. The stovepipe stays about 114°F during the evening burn cycle.

In our area we have rock and silt, not much clay. We wanted a cozy rustic-style heater that would appeal to the in-laws. Most of the thermal mass is local rock, set in an earthen mortar. The decorative copper heat shield was simply wrapped around a standard food-grade barrel.

Ernie prefers lower temperatures, Erica likes it cozy. So we keep our home around 65–70°F in the daytime, up as high as 75° some evenings (Erica sits on the heated bench, while Ernie goes outside in the snow if he's too hot). The next morning the heater surface is still in the 70s and the house a comfortable 60–65°F. We start the stove in the afternoon or evening during the winter, burn a little longer or add a comforter to the bed during cold snaps, and in Spring and Fall we may run it every other day. We burn about 1 cord of softwoods (pine, larch, and spruce) for all our annual heating.

Our neighbors use a very similar design with a longer bench to heat an 1800-square-foot home (see photo). Rather than wrestle with fieldstone, they built a brick façade, then filled around the pipes with tamped earth. The deck around the barrel is dry-laid brick on sand, and there's an optional fold-out bed at the cool end of the long bench.

At first, when installing the Rocket Mass Heater the neighbors did not take out their existing small iron woodstove—instead, they built an addition onto the living room for the heater, and waited to see how it worked. After the first month, they got rid of the interior wall. After the first winter, they got rid of their old stove, but the furnace is still there for backup.

With the thermostat set to 68°F, they run the Rocket Heater in the daytimes or evenings to get the house well into the 70s before bed. (The furnace won't kick on while the heater is in use.) The furnace may start up around 4 AM to supplement the home's heat until the sun comes up again. Their Rocket Heater uses less than half the wood that their woodstove used, and the furnace bills have dropped to about a fifth of previous years'.

What our heater and our neighbors' heater have in common is a fairly standardized Feed Tube, Manifold, and chimney design, but limited earthen masonry. We like working with cob when we can get it—but we draw the line at importing bagged sand and clay.

For the Feed Tube area we like firebrick, either new or reclaimed. This comes in a standard size, so we don't have to recalculate the dimensions every time. We have experimented with castable refractory materials, and we have made our own clay-and-perlite Heat Risers but agree with Ianto that the most durable Risers are brick.

Half-thickness firebrick works nicely for Heat Risers. Full firebrick works best for the lower firebox. Insulating kiln brick does okay in the Heat Riser, but is not as durable as solid brick. We like to add a layer of plaster to double-seal the joints and protect the soft materials during maintenance. With dense brick, we often insulate the Heat Riser

Photo: Erica Wisner

The neighbors' heater, in brick. The pipe in the bench is surrounded is 4"–6" of tamped earth all around. Ducting is 8" diameter. The cleanout is a T in the pipe end.

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with mineral wool caged in hardware cloth. We also like perlite insulation (2") stabilized with clay slip in a metal container.

We now build most of our heaters with:

16"-high Feed Tube (takes most standard firewood),

24"-long Burn Tunnel, and

48 to 52"-tall Heat Riser with a tapered top. The Heat Riser stops about 2 inches from the barrel's inner surface. With firebrick, the firebox is 7" by 7.5".

We don't use any cowling or barrel over the Feed Tube. We just make a flat hearth to surround it. We cut or break our firewood to under 16" long, and control the air intake with one or two bricks that slide across the opening.

We omit the ash pit at the fueling end. A flat floor is easier to lay on a level foundation, easier to clean, and tends to show only mineral ash (indicating a complete burn).

Ernie particularly likes a barrel-and-a-half construction for the Manifold. We cut the bottom barrel away to fit snugly around the bricks and be flat on the hearth floor (see photo at right). We seal the two barrels together thoroughly, yet can remove the upper barrel for maintenance. Any leaks in the Barrel/Manifold area are a huge performance problem, so we triple-seal with a woodstove door gasket, high-heat (300°F) foil tape, and then the original band clamp from one of the barrel's lids. If we include a removable lid on the top barrel, we use the gasket and clamp.

Wherever possible, we follow the masonry heater tradition and double-seal all the active channels. For the firebox, that means clay-sealed brick surrounded in soft insulation, then a complete wrap-around masonry casing such as cob or mortared stone.

For the barrel, we wrap the bottom edge in cob from the inside and out, and seal any openings from both sides. For example, we often add a layer of foil tape or a woodstove gasket to the cleanout caps. For the ducts through the bench, the pipes are the primary seal and monolithic earthen masonry is the second. For clients who use some other kind of masonry mass (like pouring in pea gravel for a portable model), we recommend taping all the pipe joints before adding the mass, and building a good secondary seal.

Corners are usually where thermal expansion cracks start. We include some flexible rock wool, ceramic fiber, or fiberglass gasket as an expansion joint anywhere we think heat expansion may threaten those seals.

We insulate underneath the first course of bricks and around the firebox with 2" of clay-stabilized perlite, 1" refractory (Duraboard, rockwool, etc.).

Photos: Erica Wisner

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Insulation for the Heat Riser: 10' x 24" refractory wool blanket in a wire mesh cage (approx. 4' x 5'). We use two 55-gallon drums (or any matched pair 18"–24" diameter). Preferably food-grade, with clamp-on lid, paint removed. Sealing between the barrels: 6.5' of ¼" woven woodstove door gasket (double if both barrel and lid are removable). Foil tape (300°F rated); stove cement (1200° or 2000°F rated).

Tall woodframe buildings are leaky and tend to draw a LOT of warm air up into the attic and out the roof vents. They basically act like a chimney themselves. At least some of this convective ventilation is necessary for building and human health (about ⅓ of the home's volume per hour is considered minimum), but the result is that a cool chimney stack may not be able to out-compete the building's own draft. Wind exposure, especially gusty winds, can seriously hurt the performance of horizontal exits, slowing the burn and sometimes backing up smoke.

So we bring the chimney up vertically through the roof, near the ridge if possible. Where roof penetrations are technically challenging (as in membrane roofs), we exit as high up the walls as possible and bring the chimney up above roof height.

Insulation helps protect any pipe outside the building from super-cooling. (As insulated chimney sections are far more expensive than single- or double-wall flue pipe, building most of the chimney inside the house can save costs. It also allows the home and chimney to benefit from each other's warmth.)

Our standard design usually runs 20–40 feet horizontally before going vertical. We try to exhaust above 100°F to maintain draft in that vertical exit chimney. For mild climates, even higher exhaust temperatures may help improve draft.

We like to bring the Exhaust Flue back near the barrel before exiting (as pictured for our neighbor's brick-façade heater). This helps prime the exhaust using waste heat from the back of the barrel. It also helps visually define the barrel as a hot stove, not a convenient shelf for flammable objects. Many of our clients keep a kettle or potpourri-humidifier on their stoves for that reason.

We have published our heater's full as-built drawings and builder's notes (Cabin 8" RMHeater) online. We also have building pictures and permitting anecdotes about previous heaters available on the same website, www.ernieanderica.info/shop.

Detailed step-by-step building outlines and rules of thumb are laid out in our book *Rocket Mass Heater Builder's Guide*. This book also includes a printable operation and maintenance manual, permitting considerations for local building officials, and technical notes—all the "numbers" that were omitted from *Rocket Mass Heaters* to create the concise and elegant volume you now hold.

—Ernie and Erica Wisner

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KIRK "DONKEY" MOBERT *has contributed endless curiosity, creativity, and hard labor to the evolution of the Rocket Mass Heater and to this book. He runs a Natural Building school called Sundog, is founder and tireless moderator of the first online forum on Rocket Mass Heaters, and lives in a remote beautiful location on the Northern California coast with his family and several kinds of Rocket. He designed and built for his neighbors Nathan and Gillian a Rocket-fired sauna. Nathan and Gillian love it. They traded some of their redwood trees for milling services and he built a 9′ x 9′ timber-frame sauna with 6-inch-thick walls.*

Find Donkey at www.sundogbuilders.net.

Photo: Nathan Ramser

The "Trip Wire" brick is the second brick in the sequence in the Burn Tunnel and its arrow faces downstream.

When my friends Gillian and Nathan asked me to build them a cob sauna, I had already been thinking about this application of a Rocket Mass Heater for some time. Quite a few cob saunas out there (concrete ones too) are all thermal mass. I've noticed that all the mass soaks up a lot of heat. It seems you have to stoke the stove triple-time—once for the people and twice for the building itself—to achieve sauna temperatures. I wanted to make more heat available to the people by not installing mass. So the building is as insulated and lightweight as I could make it and the Rocket Stove is as well: a Rocket Mass Heater without the mass. As a result, much less wood is used and 30–45 minutes after starting the fire, it's sauna time.

To radiate more instant heat into the room, the space inside the barrel is larger than in the typical Rocket Mass Heater. The Heat Exchange Barrel is set high—about a hands-span above the Heat Riser—and there is more space around the Riser as well, about 5 inches. That kind of barrel gap is good for Rocket Mass Heaters too. The gap at the top of the barrel can be 2–3 inches, or it can be a whole 'nother barrel parked on top—leaving the insulated Heat Riser the same height, just extending the barrel by welding another one on. In the large space, gases mingle randomly and find their way out after giving off more of their heat. The hotter stuff goes up and hangs out until it's cool enough to drop instead of being pumped. If you are familiar with a "bell stove" this is basically the idea.

The Heat Riser is two concentric round steel pipes with perlite-clay slip packed in between them. The outer jacket is an old water heater tank; the inside is ¾" x 8" steel pipe. I expect that to burn out before too long, because it gets too hot inside these Combustion Units for steel, but that's why I do the perlite-clay slip: after the steel goes away, the perlite-clay mix will do the job on its own. Recently, I've begun using Sono Tube concrete forms to mold the Heat Riser, and so far it seems to work. Why use the steel if I know it will burn away? Because I had it and it was a handy foundling waiting for a worthy job. I'd rather use free materials considered "trash" than buy something new.

I incorporate two innovations of the Rocket Mass Heater that are believed to improve efficiency: The Trip Wire and the P-Channel.

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Photos: Leslie Jackson

The Trip Wire. I use an angle grinder with a basic masonry blade to reveal a sloped triangle, which will face down onto the Burn Tunnel from above, in the position of the second brick in the series, its arrow pointing downstream.

One way to make a Peter-Channel. I would use something that's heavy enough that it won't burn away right away in the heat, or bend.

The Trip Wire, a small outcrop on the face of the second brick of the Burn Tunnel, is created by carving away enough of the brick to leave a ramping triangle on the side facing the fire and pointing downstream (see photograph above and on previous page). It effectively trips the gases into a spiral and draws them into the center, which cleans up the combustion.

I peeled open a water tank for the sheet steel.

The Peter-Channel (or P-Channel, for short, P for its inventor, Peter van den Berg, see his case study, page 110) directs air directly onto the fire downstream from the fuel, into the flaming area. There are several beneficial effects. When the incoming air passes the first brick, that brick is cooled, preventing it from crumbling from thermal shock. Preventing that brick from heating up so much will keep it from competing with the chimney; that hot brick can pyrolyze the wood setting against it, which will ignite and smoke back. It has also been seen without a P-channel that when the fuel is packed too tight against the front, downstream side of the Feed Tube, it can constrict airflow, causing the stove to burn dirty. All of these effects can be reduced or eliminated by the addition of a Peter-Channel, which can be designed in from the beginning or made later if need be as an add-on.

The P-Channel adds fresh air into the fire.

What's in the mix. I learned that wood ash added to my local clay slip makes really good

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super-cheap refractory cement. It really helps with the high temperatures. I use it to replace sand in my high-temperature mortar and as an all-purpose schmeer, filler, and sculpting/smoothing putty for demanding high-heat areas. I take clay slip that's screened fine (through a fly screen) and mix in enough wood ash (also screened) until it's like a thick bread dough. This dough is my basic mortar mix, which can be spiced up with other ingredients for different needs: chopped straw, wood chips, rice hulls, horse manure, and sand in various amounts and sizes depending on the situation.

—Kirk Mobert

The foundation is a typical rubble trench, with a French drain. With gravel up to 3 feet deep, the floor is itself a drain. They can pour water on the hot barrel for steam, and moisture from the sauna flows down through the gravel. The sauna's Rocket Stove is built halfway into the floor with the whole barrel exposed. The heater's purpose is to efficiently and quickly radiate its heat into the room.

Photo: Kirk Mobert

I like to run it while I build. That way if I detect a problem I can change the details while the materials are still wet and pliable.

A typical sauna session uses about this much wood.

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MAX & EVA EDLESON *are farmers, natural builders, masons of devices for wood-fired cooking and heating—and now parents! They are coauthors of a wonderful book,* Build Your Own Barrel Oven: A Guide for Building a Versatile, Efficient and Easy-to-Use Wood-Fired Oven *(HandPrint Press, 2012). An important contribution Max and Eva make to the world of Rocket Mass Heaters is that they are our envoys into the world of masonry heaters. Max's case study reflects these influences. (You can see the completed stove on page 15.)*

Find Max and Eva at www.firespeaking.com.

Photo: John Allen

I like to think of Rocket Mass Heaters as being on a heating continuum, rather than as different from other masonry heaters or even metal stoves. This provides a lot of room for creativity while our knowledge grows about this way of building for fire. The Rocket Mass Heater we built in a Natural Building event called *Bioconstruyendo 2010* in Patagonia is an example of this kind of combination of ideas. Considerations included having the firebox near the door to be able to stack and dry the wood just inside plus a platform that would accommodate a twin-size mattress and daybed/sleepover pad. I added the following criteria: cleanouts to give good access to the inside of the stove, and a bench of dense adobe brick.

There are small doors for access to the flues to clean out fly ash and creosote and to do other maintenance, as well as potentially tinker and tune

The building was framed from recycled barn timbers, and the walls were filled in with a combination of straw bale and adobe to create a very tight passive solar building.

Photo: Jon Santiago

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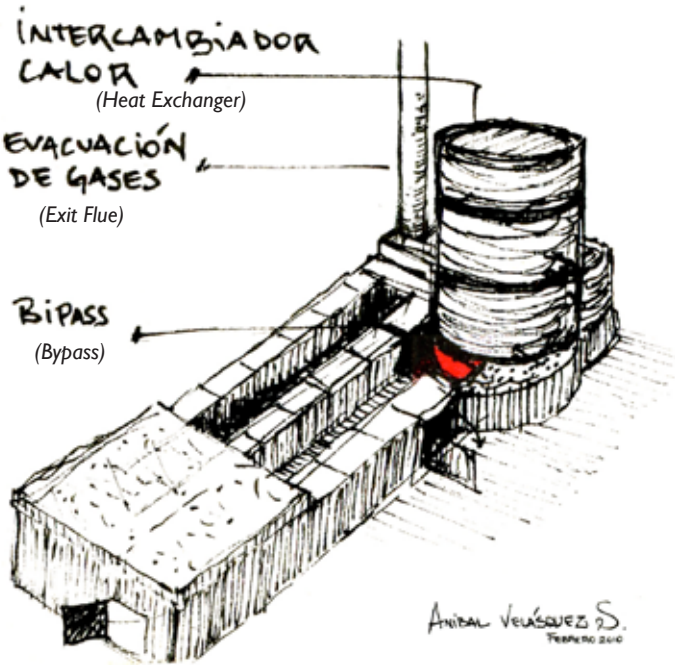

the passageways. A good guideline is to provide cleanouts at the bottom of every vertical smoke pathway and at the end of every horizontal run. One door can provide access to two flues when placed in the middle of a run. We design our stoves for cleaning with brushes, rakes, and dustpans rather than a vacuum, so the stove can be independent of electricity.

The soil at the workshop/building site in Patagonia is *very* clayey. It is difficult to make into cob because the chunks are hard to break down; it is much easier to soak the clay-rich soil to a wetter consistency, mix in sand, and form it into adobes. For the densest bricks, it means making the mix as dry as possible (as all water that escapes leaves air pockets) and packing in as much sand as possible—no straw.

This design is simple and relatively foolproof. One interesting detail the layout drawing (above) shows is the small bypass. When the stove is initially sluggishly pushing toward the chimney, the narrow slot is a short-circuit providing an easier route. Once the stove kicks into action, the larger volume of gases mostly follows the longer but more spacious route. If you make the gas slot too big, you leave a permanent short-circuit and the longer portion of your bench will not heat up. Ideally, a bypass would have a damper, providing a means to open and close easier routes to the chimney.

To those who are accustomed to the process of building a Rocket Mass Heater as described in this book, the main difference is the use of adobe bricks in most of the stove's construction.

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The heater has been in operation through three winters. The two inhabitants of the building responded very positively about its performance. It very adequately heats the space and provides a great deal of comfort in a region with fairly cold winters.

The generally collaborative spirit of Rocket Mass Heater builders is a nice environment for creative innovations. Here are some of the advantages and disadvantages I find:

The Rocket Mass Heater requires an intelligent user who spends a significant portion of the day in the space that he/she is trying to heat. It is unforgiving in its requirements for good wood preparation. The wood must be seasoned and dry and very good kindling must be on-hand for the duration of the winter. This heater is most suited for spaces whose floors are either earthen or concrete because of the heavy and relatively spread-out nature of its materials. Cob cottages and garages are good candidates, while the light, elevated wooden floors of average North American construction present a trickier starting point.

The mix of quick and slow heat also means it is a good solution for passive solar buildings. In short, it is ideal for people who derive satisfaction from having a relationship with their stove and the processes that surround it, who enjoy sitting down at the end of the day to warm their bones on a pleasantly warm bench they have built, and whose love for the stove and the healthy work of adequately preparing its fuel make the stove's sometimes finicky/fussy disposition worthwhile.

Some of a Rocket Mass Heater's strengths can be weaknesses, depending on the context. In greenhouses, the need to tend and feed a Rocket Mass Heater is a disadvantage. These applications are more suited to a batch-style firebox where you can put in a sizeable load of wood, burn a clean hot fire for 2 hours, and quickly store the heat you will need over a 24-hour period. As mentioned above, the fact that Rocket Mass Heaters generally have a relatively large footprint means they are tricky and potentially costly to build upon the joisted wood floors prevalent in North America. The more vertical orientation of other masonry heater formats minimizes the footprint of the foundation necessary and works well in spaces where a bench is not desired.

I think the biggest challenge Rocket Mass Heater development faces is consistency and reliability in performance, and also ease of use. We need to continue to identify the key aspects that make a Rocket Mass Heater sing to ensure that the effort that goes into installing it returns in warmth, comfort, and happiness.

—Max Edleson

Place the Barrel over the Heat Riser to examine how its shape—both interior and exterior—interacts with the ones around it. This is essential to ensuring good flow and an integrated design.

The 7" exit chimney is installed. Most of the system is sized at a cross-section of 8" and then reduced at this end to maintain velocity of gas flow.

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LASSE HOLMES *lives in a beautiful place in Homer, Alaska. The best brewer in the state, he is also a natural builder and lives in a timberframe and strawbale cabin that he built in the mountains overlooking the Kenai Peninsula. Lasse turned up on Kirk's forum, introduced himself, and started sharing his experiences with adapting a Rocket Mass Heater for the heating needs of the cold cold North.*

Find Lasse at www.canyonartz.com.

Photos: Leslie Jackson

Mass heaters touched my soul the first time I experienced a traditional one in Europe over 20 years ago. I'll never forget the generous depth of its heat radiating from the beautiful masonry, warming me to the core much like sunshine does. David Lyle's *The Book of Masonry Stoves* fed my armchair appetite for this kind of heat for a few years as I dreamed about how I could fit a multi-ton mass into my own home. I live in a 650-square-foot home in Alaska without the necessary foundation for a traditional masonry stove, so I could only dream about having one. Then this book in your hands hit the streets, and I could not contain my excitement when I realized that there was a more approachable way to build one, by spreading the weight over more floor area. Eventually, I could only quench my intense thirst by building one. Four winters and nine heaters later, the Rocket Mass Heater has been adapting to the intense needs and conditions of heating in south central Alaska. Our heating season is (at least) 9 months, during which 3 have almost no solar gain.

The first Rocket Mass Heater in our area was for my own home that had previously been heated with about 350 gallons of fuel oil and 3 cords of spruce per year. The first winter with a Rocket Mass Heater, my fuel needs dropped to 2½ cords without burning any fuel oil, while my comfort level went up. Very encouraging indeed!

The number-one need for a Rocket Mass Heater to fill is comfort: being warm and snug. When I evaluate how efficient a particular heater is, comfort, is one of the most important factors. After I built my first Rocket Mass Heater, I started teaching workshops to help others get hands-on experience. With each new heater constructed, more enthusiastic members have been added to a team of individuals who have helped shape the "Alaskan-Style Rocket Mass Heater." Each one is uniquely built to the owner's needs. Each is constructed to be easily maintained and adaptable as conditions change.

Since this book was published, the internet forums have been dynamic places for us Rocket pyros to exchange ideas and experience. So many different needs are sprouting quite the variety of approaches. The creative juices are really flowing. What exciting Rocket times! We are so very grateful for all the sharing that has greatly influenced

The efficiency of comfort and love: Joey and her son Walden Turtle Kraszeski on a late winter's day.

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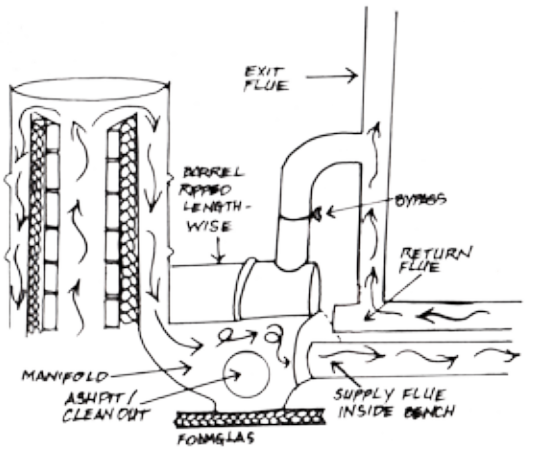
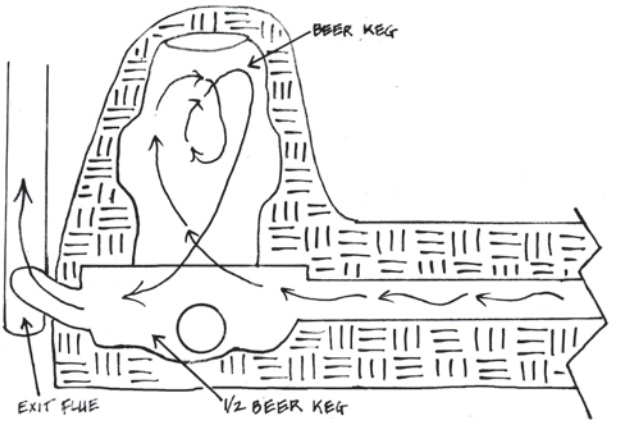
our Alaskan-style Rockets, especially as we are geographically so removed from the hotbed Rocket scene of the lower 48 Pacific Northwest. And, by turning each new project into a workshop, we share hands-on experiences and empower many individuals to build their own.

The mass bench in my house is L-shaped with a 6-inch flue that doubles back on itself and runs about 24 feet horizontally, surrounded by local stone and urbanite. Three-quarter-inch type-K copper tubing was laid in the mass both for alternative solar thermal heating and for moving heat from the bench as a low-tech heat exchanger. (Always include a pressure relief valve!!!) A diverter valve (a.k.a. bench bypass) was installed to make things easier during odd wind conditions or cold startup (see illustrations).

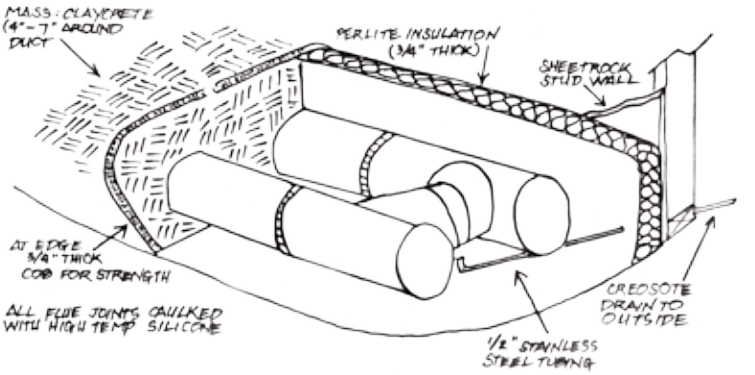
After a few winters' use, I made some modifications to the mass bench. First I added a drain at the low end of the horizontal run to prevent condensate running out when bringing the cold bench up to temp. Exit temperatures higher than 250°F, told me I could still extract more heat. I cobbed in a stainless beer keg to make a "bell" heat exchanger (see illustrations).

My first Rocket Mass Heater was built straight out of this book. And I decided to convert a woodstove as a "pilot" unit that I could fire and dry my bench with, and then remove to build something more permanent later, after gaining some experience. I took a classic horizontal-feed woodstove and lined it with firebrick, added an insulated Heat Riser, and covered it with a beer keg "barrel." Unfortunately, this temporary one worked so well that I didn't replace it for several years! I was able to bake in it and it had much bigger fuel capacity.





A horizontal beer keg ripped lengthwise becomes a condensation tub, and a vertical beer keg with the bottom cut out is a bell, where hot gases hang out and cold gases leave.


MASS: CLAYCRETE (4"-7" AROUND DUCT
PERLITE INSULATION (3/4" THICK)
SHEETROCK STUD WALL
AT EDGE 3/4" THICK COB FOR STRENGTH
ALL FLUE JOINTS CAULKED WITH HIGH TEMP SILICONE
CREOSOTE DRAIN TO OUTSIDE
1/2" STAINLESS STEEL TUBING

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Horizontal-feed kit door assembly in an earthship outside of Homer, Alaska.

The satisfaction of that woodstove-to-Rocket conversion inspired me to come up with a simple way to repeat the success of the design with a firebrick Rocket oven built in place.

Most people in Alaska are very comfortable with a traditional woodstove, in that if you keep it cracked open you get it to roaring. But working with a downdraft configuration is another level of adjustment.

Because of our extreme heating needs, we also need to burn a larger amount of wood than is feasible in the standard 8-inch downdraft version of a Rocket Mass Heater. While in a moderate climate you can feed your Rocket for 45 minutes to warm the house all day, in Alaska you would need to continuously feed it for several hours. So we adjusted the design. The horizontal batch-box provides this familiar transition. By loading up the batch-box you can still do several loads in it, but you don't have to baby it so much. With that there is a sacrifice in efficiency but a gain of overall effectiveness, as operator comfort is integral to efficiency.

Photo: William Johnson

The horizontal-feed "kit" will be fitted with a custom door. A plywood form holds the arched bricks steady until mortaring.

So began the evolution of what is now a "kit" that we make with a steel angle frame (2 x 2 x ⅛") that bolts to a custom door-piece and supports a firebrick arch-ceiling oven combustion chamber. Quickly we realized this horizontal-feed combustion chamber has the added benefit of being a masonry oven, which after firing you can bake all kinds of foods in! For that, we make a wooden door "plug" (similar to the ones on cob ovens) inserted at the time of baking to stop airflow—therefore premature cooling—through the system.

At first we did Heat Risers out of thick-wall steel pipe, but they burned out quickly (especially in the 8" systems). Now we only use firebricks or refractory cement. Perlite-clay has worked well for the insulation, although ceramic wool (Kaowool) is the preferred material when a narrow Heat Riser is called for. Mostly we've used the standard oil drum barrels (we like the clamp lid system swapped for a thicker steel top for cooking) but recently we built a masonry "barrel" out of lower temp (cheaper) firebrick with a ⅜"-thick steel top resting on stove gasket material. Despite trade-offs such as the loss of the quick radiant heat from a thin steel barrel, plus extra money and work, that method addressed the need to have a different aesthetic than the oil drum. The firebrick barrel can then be encompassed in mass, plastered, sculpted, tiled, or faced to suit.

We continue to play with the design and materials. The ash pit/cleanout area after the Manifold has become rather voluminous. The latest ones we built are essentially a bell heat exchanger created by a steel drum ripped lengthwise for a barrel vault lid (see illustration). Previously, we formed the ash-pit lid out of expanded metal lath and cobbed it over, but the ripped barrel simplifies and speeds things up. Frequently these ash-pit lids are the location of the mass bypass exit

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in the top for lighting the stoves when conditions demand it. Getting the mass bench roughly right in the beginning is very important as the Combustion Unit is more likely to need rebuilding and can be rebuilt or modified much more easily.

The black and red patterns on this bench fit in well with a bright creative house: paint over earthen plaster.

Heat transfer. Most solid rock has a grain that conducts heat differently along the grain than across. Large slabs set into the top of a bench thus have a very different heat movement than mass that is made up of gravel with sand around to disperse heat more evenly. Soapstone has a texture that makes it naturally heat evenly, which is why it is so sought-after for the job (besides the beautiful aesthetic, of course). We have built tapered forms (for heel space overhang) that allow us to do a kind of rammed earth technique for the main mass with what we call "claycrete" (gravel, sand, and clay slip). We use clay-sand mortar for areas around plumbing or tight zones, cob with straw for the tensile strength needed on the vertical exposed surfaces, and clay-perlite for insulation against the wall of the building (if needed). Nice looking stones, tile, or other decorative elements can be set against the form, to be revealed when the forms are removed after drying. We use sand and cardboard forms to build negative recesses (such as cleanout accesses) by creating positive forms. This way excavation is easy after form removal. Curved wall forms take a little bit of skill to make (much like skateboard ramp construction) but are reusable on future benches, and we now have a collection to use and share in our area.

Insulation. Living with a mass heater is a relationship. One key part of the relationship that is not obvious at first is the insulation on top of the Thermal Battery. I am constantly removing or adding more layers of futons and wool or down blankets, depending on the situation. With insulation, you can get more overall heat stored at higher temperatures or pull them off to release the heat, and with surface temperatures varying from 110°F to 140°F, I have some options. After coming home from a long day in town or out skiing, it is so nice to get between warm blankets and recharge my core before even thinking about getting up to start a fire. Also, by varying the amount of insulation, I do lots of "haybox"-style slow cooking of grains and beans, or incubate fermentations; and I can remove insulation to dry foods, herbs, or clothes, or to raise the air temperature in the room. With large amounts of insulation and pre-burning extra for a day in advance, I can leave my 650-square-foot home in single-digit weather up to 3 days and not have it freeze inside. This is so valuable for off-grid cold-climate living!

I frequently talk with people interested in adding a Rocket Mass Heater to their home who are concerned about the floor space it will "take away" from their house. Once you enter into a relationship with a mass bench, you realize that—in the winter especially—it is the preferred place to be and therefore it is actually "giving" floor space. I have noticed a tendency of female visitors in particular who, after getting introduced to the bench, essentially melt into it for hours, at times making it difficult to remove them. Perhaps a human-scale spatula might need to be invented!

—Lasse Holmes

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ART LUDWIG *is an ecological systems designer, researcher, author, and activist. He has consulted for the states of New York, California, and New Mexico on water reuse policy and building codes and has developed numerous innovations which have been adopted worldwide, incorporated in building codes, etc.—all of which he has published in the public domain. Art has authored numerous articles as well as the books* Water Storage, Principles of Ecological Design, *and* Create an Oasis with Greywater.

Find Art online at www.oasisdesign.net.

We overturned a wide ceramic pot on top of the Heat Riser Barrel for an oven. It's also removable to release radiant heat.

My family lives at the southern edge of the "Rocket Stove Belt" in the Santa Barbara hills. Most of the time our heating season runs from 7 PM to 10 AM rather than November to March. That is, some winter nights only, and mostly when its raining and the passive solar isn't cranking. Our house is a 1920 two-storey summer cabin. It has a lot of glass and masonry in the first floor and most of our living space is on the second. Our Rocket Mass Heater is like the boiler in the basement, making use of mass in the floor and walls; and the heat gently rises into the rest of the house. Now that we have insulated the roof, we could get by with zero active heat, but the RMH provides an extra-sweet margin of comfort, when it's raining primarily, and makes the surface we are sitting on warm instead of not warm. And I like burning wood.

Photos: Art Ludwig

Note the bypass valve damper. This enables us to bypass 8 of the 11 90-degree bends on the way out and works really well for getting the draw started.

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Our RMH has an exceptionally long, bendy run of pipe, doing a double run through a U-shaped bench. The exit pipe follows the bench to double back on itself, and then exits near the Combustion Unit. Between the Heat Riser and the bench is a diverter valve (damper) that lets us shunt exhaust directly to the exit chimney. This works really well. It provides an easy bail-out option in case there's any smoke coming into the space. We just flip the diverter valve over and it greatly increases the draft. With the valve, you can see the physics of the bench in action, too. When it goes directly out the Exit Flue, the stovepipe might reach 500°F, but when the valve is open to the bench, it only reaches about 120°F.

Lessons learned. Now that Rocket Stoves are a more proven, less experimental technology, it no longer makes sense to assume that the whole thing will be redone before the duct rusts out. Although stainless steel costs an arm and a leg, installing it can be a good investment in not having to rebuild everything.

We had multiple challenges for avoiding fire hazards with installing the ducting, which is in places about 12 inches from a wood floor and walls. We had insulated runs of pipe with pumice around them and we had 8" stove pipe for the exit ducting. That should be okay, but it wouldn't have been if it were operated with the diverter open, which is too easy a mistake to make. It's insulated pipe, but as I mentioned in the counterintuitive physics warning (see "Slow changes in materials" in Fire! Fire!), if there's no way to extract the heat, the insulation becomes irrelevant in the steady state of the system. So we created an air path between the stovepipe and the floor: There's a bunch of holes in the cob (1" around and about 16" deep) that make little convective cells and pipe the heat out into the room and out of the space between stovepipe and wood floor. Thus, it attains a steady state with a much lower temperature than it would without those holes.

Even though it's extreme overkill for regular use, my choice in triple-wall stainless steel pipe for the outdoor run of flue with a screened outlet on the end is a port-over from my experience with greywater systems: In the case of greywater systems, inspectors have specialty knowledge, experience, and an eye for quality work, yet no concept of what's happening out in the yard; their eyes just glaze over. So what they'll do instead is look more closely at—and rake you over the coals about—the parts they are familiar with. You can suffer from this, but you can also use it to your advantage. When they see the indoor plumbing so professionally and well done, they will then assume that the rest of the system—outside, the part they are utterly unfamiliar with—is done with the same high standard.

In our case, we outfitted this space to be simple to use safely. Initially the main safety feature of the system was me patrolling; moving matches, bottles of olive oil and sleeping bags away from the stovepipe; noticing that the diverter was in the wrong position and putting it right. In preparing the house to leave for a year, we did some extensive modifications to address some of the safety pitfalls. For example, there was one small place on the bench that was dramatically hotter than anywhere else, so we added ½" of plaster. It didn't change the use of the bench, but it eliminated the pillow igniter.

The far reaches of the exhaust pipe through the bench, where it doubles back on itself, with cleanouts.

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Foamglas insulation—my new favorite substance—around the firebox raises combustion temperatures and eliminates a 300°F hot spot.

A welded steel decorative ornament around the Feed Barrel reminds us the metal is hot.

Checking the whole stove with an infrared thermometer, the outside of the clay around the firebox was dangerously hot in places. So we ended up pulling all the plaster off and putting 2 inches of Foamglas in there, then replastered. Now the down jacket carelessly tossed there won't catch fire.

There are air holes running the length of the triple-wall stovepipe (see illustration in Fire! Fire!) We wanted to cover them up, thinking to keep the heat from being lost... And then later I realized that they were what got it its high fire-resistance rating. Lesson learned!

We take the ashes out every third fire. I haven't cleaned the stovepipes yet, and I haven't measured the creosote accumulation, but there's one thing I noticed from my experience with greywater systems. When we came up with the branch drain greywater system, we ran into a whole set of problems that we'd never experienced before, because the system *didn't* fail. And we realized that if your system only lasts a year or two before it fails, there's this whole set of considerations that you don't ever really encounter. What if so much time passes that you lose track of the system parts underground? What if the ownership of the house changes twice? And so the planning horizon for a branch drain greywater system should be 20–30 years—whereas for the systems that I dealt with up to that point, it was 5 years, optimistically. With Rocket Stoves we're at a similar threshold. And so you may have pipes with no detectable creosote in 2 years, but then the system's going to end up being 100 years old someday, because it just works.

—Art Ludwig

The bench wraps the eaters at the table in cozy comfort.

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BERNHARD MASTERSON *creates artful natural homes, wood fired ovens, and Rocket Mass Heaters. He teaches a wide range of natural building techniques in hands-on workshops and through Pacific University and Portland Community College. He has built numerous rocket mass heaters and wood fired ovens of various designs since he started sculpting with earth in 2002. As an artist, designer, and devoted maker of things he appreciates the blend of science and beauty that home built heating and baking devices provide. When not helping others pursue their dreams he can be found developing his urban homestead in Portland, Oregon.*

Find him online at bernhardmasterson.com.

In 2002 I decided to embark on a journey toward a greater connection with the natural world, the seasons and gardening and toward reducing my need for cash. That dream led me to building a snug 450-square -foot strawbale and cob cottage outside Portland, Oregon. The home is heated with the sun and a wonderful Rocket Stove.

With a massive Thermal Battery I don't come home to a cool house and push a button to turn on the furnace. Instead I come home to a warm house and fire up the Rocket Stove.

Living with a heated bench provides some real treats. Few things are better than coming in out of the cold and sitting on a warm seat. Leaving the next day's clothes on the bench lets you put them on warm in the morning. Friends linger longer, and rising bread is a snap. There are some downsides of course: those same guests may stay later than you like, and you might have difficulty getting off to bed when your eyelids are heavy and the bench oh so relaxing.

Because I am more involved with the actual heating of the house, I have a greater awareness of the season. Going outside every couple of days to get firewood is an opportunity to appreciate the weather. I try to take a moment each time to feel what it is like outside, even in the midst of a winter storm.

Rocket Stoves are renowned for their efficiency and I'm surely pleased with this one. On cloudy days a 2 to 3 hour burn in the evening uses about a 5-gallon bucket of wood. For regular winter temperatures of 35 to 50°F. This keeps the house at a comfortable 60 to 65°F. The house temperature swings about 5°F, gaining that much with each firing then gradually dropping the same in the next 20-odd hours.

In an earthen house heated with a Rocket Mass Heater, I feel as comfortable in the low 60s as I do in a conventional home in the high 60s. I believe this is because in a cob house heated with a Rocket Stove, walls are much closer to the air temperature than walls in a wooden house heated by a furnace. This is much like radiant floor heating, living in a space with surfaces closer to skin temperature. I radiate less heat to the walls, making me more comfortable.

In designing our stove, we chose to keep the top of the barrel low so we could easily put large pans of water on the top for heating. The 3 gallons of water we heat on our stove each day are used for dishes and bathwater.

Using a 55-gallon drum with a removable clamp-on lid allowed us to build the drum into the wall between the living room and bathroom and still have access to the Heat Riser for cleaning. The radiant heat in both spaces is wonderful. We have, however, discovered a couple drawbacks to the clamp-on lid. One is that the bungholes and rings in the lid limit the space on the stovetop for pans. A second is when we are running the stove really hot, the lid expands and pops up slightly, which is

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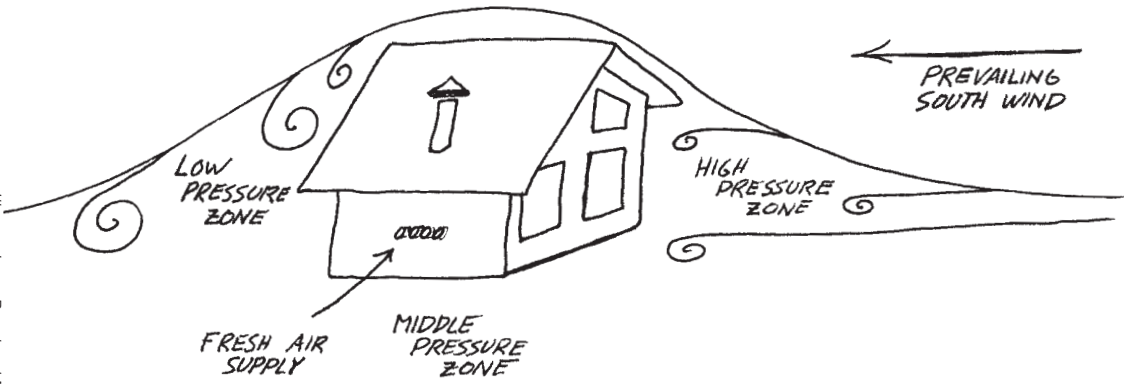
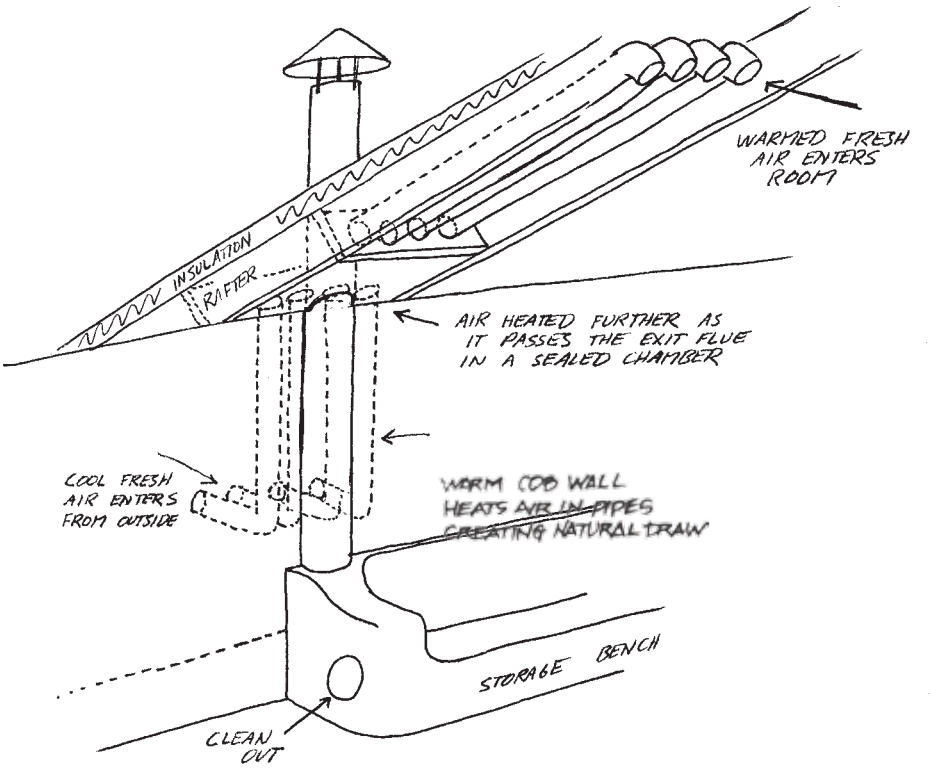


Illustrations: Bernhard Masterson

* OUR OTHER COMMON WIND COMES FROM THE NORTH AND PRESSURE ZONES REVERSE. THE FLUE STILL EXITS IN A NEUTRAL PRESSURE.


WARMED FRESH AIR ENTERS ROOM
INSULATION
RAFTER
AIR HEATED FURTHER AS IT PASSES THE EXIT FLUE IN A SEALED CHAMBER
COOL FRESH AIR ENTERS FROM OUTSIDE
WARM COB WALL HEATS AIR IN PIPES CREATING NATURAL DRAW
STORAGE BENCH
CLEAN OUT

BY PUTTING THE FLUE EXIT AND THE FRESH AIR SUPPLY ON THE SAME SIDE OF THE HOUSE, PRESSURE VARIATIONS BETWEEN THE INSIDE AND OUTSIDE DUE TO WIND ARE BALANCED. THIS REDUCES THE LOAD THE J-TUBE HEAT PUMP WORKS AGAINST TO PUSH COMBUSTION GASSES FROM THE HOUSE. CROSS-SECTIONAL AREA OF THE FOUR INCH P.V.C. PIPES MATCHES THAT OF OUR STOVE FEED TUBE.

Purchased by Johnathan Yelenick, johnathan.yelenick@gmail.com #11023292

a little startling when it is covered in pans. A lid made from thicker sheet steel may solve these imperfections.

I still think the removable lid is a net gain. To seal the bungholes and lid, I removed the rubber gaskets and replaced them with aluminum foil "ropes." This worked well and the aluminum did not degrade at all in the first year of stove operation.

Installed in our bench are two 6"-diameter ducts for heat transfer to the thermal mass. Our bench is about 16 feet long. I believe if it were longer we would get more heat out of the exit gases, as flue temperatures range from 170 to 250˚F as gas exits the house.

The ducts in the bench vary from 2 to 4 inches from the surface, which turns out to be an unintentional asset. We can move around from hotter to cooler parts of the bench depending on our comfort. The 2-inch spot may be a little on the thin side and can get quite hot, but it sure reduces the time it takes when we set loaves on the bench to rise.

The first stove I built is in a drafty workshop. When we had strong winds hitting the side of the shop where the flue exits, it tended to backdraft. I solved this problem by opening a window on the windward side of the shop to balance the air pressure inside with that on the upwind side. So for our house stove, I put a fresh-air supply on the same side as the flue to equalize pressure. This has worked well, and I built a sort of heat exchanger with the flue to take the chill off the incoming air (see drawing).

One of my neighbors laughed at our funky stove and the small size of our woodshed as we were building. Now when he comes to visit, his favorite place is on the Rocket bench. And he is envious that we can collect and split our season's supply of firewood in 2 days because we heat our house with about a cord of wood. Less wood chopping means more time on the bench, and that is always a good thing.

—Bernhard Masterson

Photo: Bernhard Masterson

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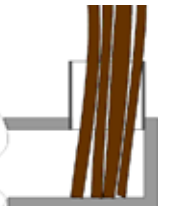
PETER VAN DEN BERG *lives on the west coast of The Netherlands. He is a retired boat repairman, spending most of his time experimenting with masonry- and Rocket Stoves, and has been very active in the online discussions about Rocket Mass Heaters, bringing practicality, experience, and science. Intrigued with the concept of Rocket Stoves, he's been tinkering in his lab to combine the best parts of Rocket Stove tech with the scalability and science of masonry stoves. We're grateful to Peter for his painstaking research and for making his findings public.*

Peter is often found at the forum at www.donkey32.proboards.com
See www.donkey32.proboards.com.
Choose "Experiments/results" then "Small-scale development."

During summer and early fall of 2011, I built several small Rocket Heaters of only 4x4 inches, the first one steel duct throughout with a steel "bell" to replace the cob bench. At first, as a way to compare the Rocket Mass Heater against an equally small and notably efficient stove built like a "cyclone stove" [a small alcohol-burning stove made from an aluminum can and relying heavily on turbulence to make it work], I wanted to evaluate them side-by-side, so I scaled the Rocket Mass Heater down to the same size as the cyclone. I used a Testo 330-2 gas analyzer to establish the relative performance figures. After a month or so experimenting, I came to the conclusion that the cyclone needed quite a strong draft from a large chimney and strong winds. So the cyclone was ditched and the Rocket Heater was put to more tests and changes in an attempt to improve upon its already excellent qualities.

The purpose of the tests was to find an excellent combustion chamber to use in a masonry stove in our new house-to-be in a couple of years.

All subsequent test versions of this 4-inch Rocket Heater had some disadvantages; some did better than the plain by-the-book one of the same size in very specific circumstances such as high winds. The main goal of all this work was to persuade the stove to stabilize its spiky behavior, in that every time the fuel shifted down or fresh fuel was added, an overload occurred in the produced hydrocarbons. These hydrocarbons couldn't be burned by the stove immediately and the peaks in the CO level were large enough to be accompanied by smoke. The stove was capable of delivering very nice figures, but it wasn't able to do so in a reliable way. If I could stabilize this, I would be glad to use it in for combustion our new masonry stove. When I'd let the fuel in the Feed Tube lean to the side of the Burn Tunnel (see drawing at right), the most obvious shortcoming of this stove was shown by the Testo. It proved possible to control the CO level to some extent this way. Leaning into the Burn Tunnel sent the CO level sky-high.



Introducing the Peter Channel. Unblocking the entrance of the Burn Tunnel clears the exhaust gases. A simple plate, inserted in the Feed Tube parallel to the first brick over the Burn Tunnel, and at a slight distance from it—creating a slot—keeps the entrance free at all times and easily resolves the problem. The best-sized opening appears to be 5% of the system size. The plate is a bit longer (hanging down under the ceiling of the Tunnel by a distance that is the same as the gap), which provides a better overall performance, to my own surprise. (Also see photos in Kirk's case study, page 96.) The plate induces some turbulence and adds fresh air into the process. The air heats up quite a bit and thus this air inlet proves to be self-regulating. When the air is heated on the way down, there is resistance, because warm air needs to rise. The hotter

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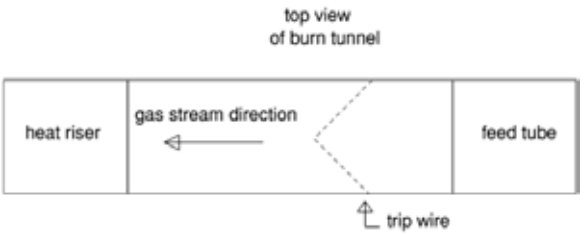
the air gets, the higher the resistance is, so by heating up the stove, the entrance of air via this path is minimized automatically.

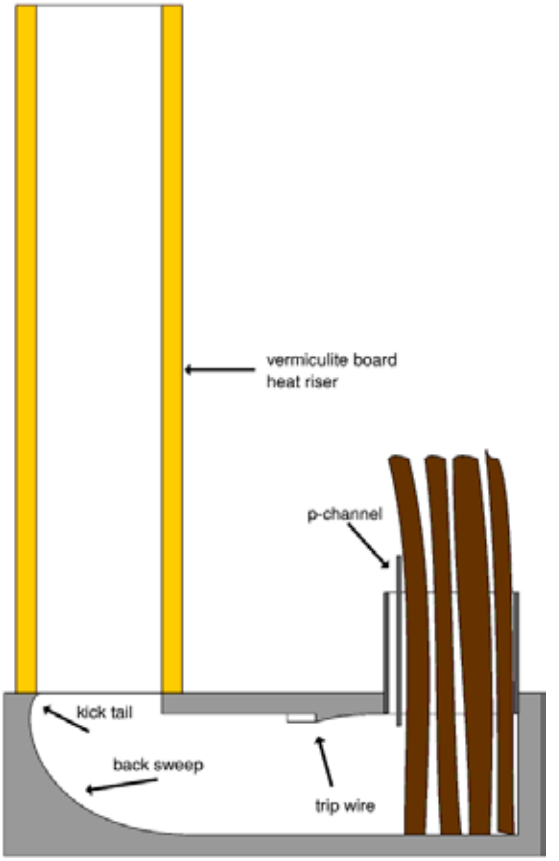
The effect is increased turbulence and higher combustion temperature.

Introducing the Trip Wire. The most important addition is a trip wire. There's actually no wire at all; it's a term of art, used to name a feature which trips the laminar airstream to break up in small eddies. It's a part of the Burn Tunnel ceiling, coming down gently to end abruptly in a sharp ridge pointing downstream, like a wide arrow. The majority of the combustible gases—being the hottest—stream along the ceiling of the Tunnel. So I first shaped the ceiling in such a way that these gases converge in the middle. (The drawing below illustrates how it might look from above.) This was a very smart looking feature, and the expected impact was there, but not as effective as I was hoping for.



The second way I attempted to induce even more turbulence was by rounding the back end of the tunnel. My goal at this detail was to minimize drag without killing the sought-after turbulence.

Turbulators (anything that turns laminar flow into turbulent flow) are successful to some extent, so why not introduce an additional built-in feature? Of course this couldn't easily be done in steel, so I made a Burn Tunnel assembly consisting of two halves made of castable refractory material. This worked well but didn't show in the results as a serious amendment. To make it more effective, I shaped this curving back end more like an upside-down ski-ramp (see drawing at right), starting smooth at the bottom and curving up to the Riser in a progressively shorter radius. The end of the back sweep acts as an additional trip wire farther down the system. To make matters even more complicated, the radii left and right are not



the same as the one in the middle, converging the stream by this way. Another, rather unexpected effect occurs with this: ashes are very reluctant to settle down on the ski-ramp: Almost all particles were blown away and ended in the ash pit under the barrel.

These three modifications together transformed the little stove into one that could handle a quite large overload of combustible gases. The high CO spikes were a thing of the past. Even a red-hot Burn Tunnel and a Feed Tube crammed full of thin pieces of fuel couldn't get this dwarf to emit any smoke. I fiddled with other stoves in the past and was very happy to see the CO go down to less than 1000 ppm during the top of the burn.

To my surprise, the thing produced such low CO numbers as I've never seen before, enough to call the lowest numbers on the planet. And I do mean low, less than 50 ppm during every test-run to date and sometimes even zero.

—Peter van den Berg

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Kiko, as drawn by his son Isaac.

KIKO DENZER. *After taking a 10-day cob workshop with Cob Cottage Company, Kiko started building mud ovens, which are about the simplest form of mass heater. That, combined with the sculptural possibilities of mud, turned into a major occupation that spawned a couple of books (*Build Your Own Earth Oven *and* Dig Your Hands in the Dirt *see Recommended Books). Kiko has spent years teaching workshops on earthen ovens, stoves, building, and art—and building his own Rocket-heated cottage, cabin, and shop! Kiko doesn't call himself a professional builder but is proud to claim that he is the world's foremost expert on his life, which works pretty well and stays reasonably comfortable year-round without requiring too much wood (or too many sweaters)!*

Kiko's on the web at www.handprintpress.com/kiko.

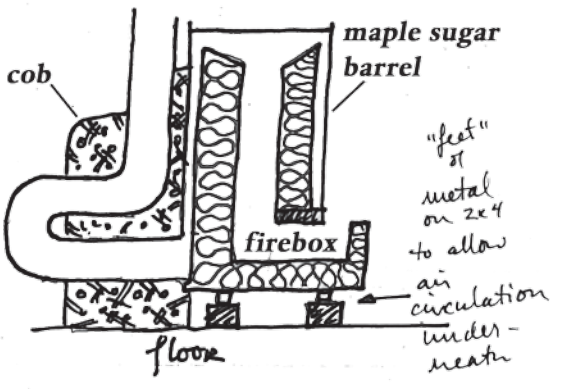
I have been heating home and shop (and water) with various forms of self-built wood-burning stove for nearly 20 years. The following three designs were adapted to particular needs, which primarily have to do with heating very small spaces (a 10' x 22' cabin, a 16' x 20' cob cottage, and a small shop space).

ONE: From modular Rocket design to masonry "heater hat"

For my small wooden cabin, I wanted a small, lightweight stove (to avoid having to reinforce the floor and foundation) that would hold more heat than the old cast-iron wood cooking range (which dropped coals out of rusty holes) and would reduce creosote and related risk of chimney fire.

I found a heavy metal box (22" square by 8" high) and a 19" maple sugar barrel. These would only fit a 6" system with a proportionally small firebox. I set the box on a square steel channel on top of wood legs to keep from burning the floor and to provide another radiant surface (see drawing—the 22" box isn't really indicated, but it contains the insulation up to the top of the firebox). The Exhaust Flue, encased in cob, rested directly on the floor, making a footprint that was about 22" x 40". I also wrapped the bottom third of the barrel in cob. If the existing chimney hadn't been right above the stove, I'd have thought about sending it out horizontally through a wall.

The stove performed well, perhaps because the total vent run was proportionally short, but after we had our first child and moved into the larger cob space, the cabin turned into office and guest room. As we couldn't train and/or supervise short term visitors in stove use, we started to worry about burning sticks falling out of a poorly monitored



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firebox—and without daily firing, initial heat-up also meant watching two stoves in separate buildings. So when a friend offered us a small (free!) box stove based on a Jøtul design, we said, "Yes, please!" Although it was old (illegal) and some of the baffles were seriously damaged, it worked great. The Jøtul design keeps the firebox hot with iron baffles on the sides and top, and burns hot and clean—at least when the damper is wide open. And you can stuff it with wood, light it, and walk away—no worrying about burning bits falling out. The downside, of course, is that the heat gets intense very fast, and when it goes out (in about 20–30 minutes, depending on your wood) you get cold again.

A year or two later I joined Max Edleson on a heater build with Jerry Frisch of the Masonry Heaters Association, and then I helped Max build a masonry greenhouse heater around an old metal box stove. After that, I started thinking about putting a pile of masonry on top of my little cabin stove. As the stovetop itself was tiny (just 12" x 20"), I poured a larger pad (18" x 24" x 1.5") from high-temp cement and set that on top of the stove as a base for the masonry (I cast an opening at one end to match the opening in the stovetop). On top of that, I fabricated a combination of an oven chamber, baffles, and flues, with a metal damper on top.

Materials consisted of an idiosyncratic assortment of standard and split firebrick, inch-thick clay flue tile, and recycled hollow bricks from a defunct local manufacturer. I also took the old warped iron baffles out of the firebox and replaced them with unmortared split firebrick (standard firebrick is 4.5 x 9 x 2.5 inches, a "split" is 4.5 x 9 x 1.25). The splits get knocked out of place occasionally and fall into the firebox, but they go back easily.

I mocked-up and tested the design in the shop, but it didn't perform as well as I wanted it to once I'd built it in the cabin. The third was the charm, so I finished it with textured and colored mud plaster (photo at right). It lights up as easy as any old box stove; and you never damp it down, so it always burns hot and clean. I want to rebuild it in the next year or two, adapt a better cleanout, and examine the inside for ash and carbon deposits.

The additional masonry (about 300 pounds) stores plenty of heat to keep the cabin warm. The fuel that used to warm me for an hour, overheat me for an hour and then leave me chilly after an hour-and-a-half, now keeps me warm just about all day. Most days, there's enough residual heat that I can start my office work at the same time I start my fire. And after a couple of hours of fire on a chilly morning, the little "white" oven is hot enough to bake breakfast rolls or roast a few 'taters! The metal firebox, however, itself does not give off much "instant" heat. That's the difference between a brick-lined and a metal firebox; the latter throws so much heat so fast that clean burn temps (1200°F and up) are virtually impossible.

It really was cobbled together—proof, I hope, that such a solution really isn't very complex or difficult—it's just a few basic principles about how fire, heat, and gases work together. If you follow those principles, they can keep you warm—and safe—if you really follow them!

Photo: Kiko Denzer

There is a wonderful silent video of the construction online at: www.handprintpress.com/authors/masonry-heater-hat-videos-construction-details.

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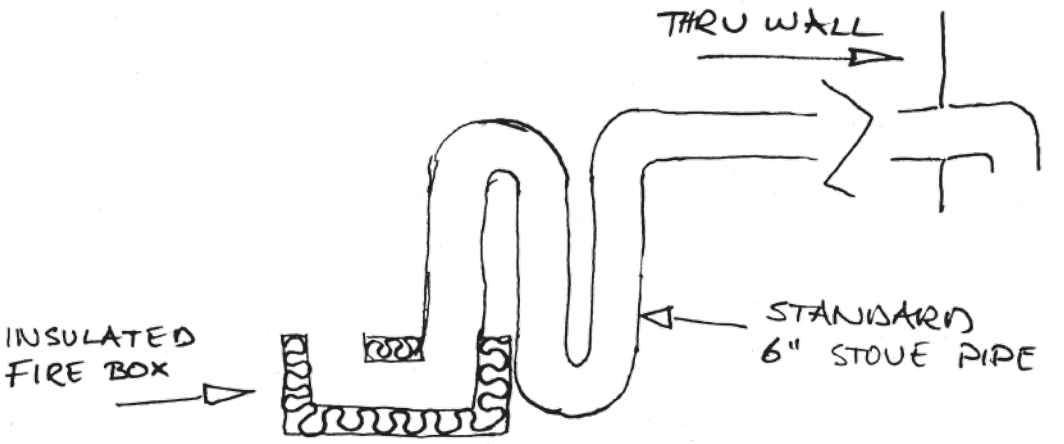

Illustration: Kiko Denzer

Rocket radiator for the shop, First Edition

TWO: Rocket radiator for the shop

In my workshop, I didn't need a masonry heater so much as a clean-burning stove that would warm me up quickly and keep me warm while I worked without using much fuel.

My first one was a 6" system. Because it was easy to toss a few small sticks in the stove as I passed, I wasn't worried about the need for stoking. However, instead of an insulated Heat Riser and Heat Exchange Barrel, I used what I had, which was just a lot of 6" pipe (no barrels!). So I simply made a J-tube—firebox, burn tube, and chimney. At the top of the chimney, I attached more pipe, some of it connected by doubled elbows (for 180-degree turns). That basically gave me a big metal radiator for fast heat with small fuel for as long as I wanted to feed it.

Later, when I took the 22" "Box Rocket" out of my cabin, I rebuilt it in my shop, with a barrel, but minus most of the cob. I did arrange the top bit of pipe at workbench height, however, made it a bit longer, and assembled cinder blocks and lumber to support a 3-inch-thick cob bench that came in direct contact with the top third of the top piece of flue—which did warm up, sometimes hotter than I could stand (sit)!

THREE: (More or less regular) (Cob) Cottage Rocket

In my little cob cottage, I have built four or five stoves over the past 15 years or so (lost count!). Save for the most recent one, they were standard 8" systems which got better with every build (especially if you don't count the stupid mistakes—always check the cross-sectional area of your Manifold!) The biggest variation was that instead of pipe (short on materials again!) I used stone and adobe to fashion square channels under my bench.

The part of the bench top that was made of limestone and soapstone heated up really fast, and is very resistant to all the things that mess up mud plasters: pants with rivets and dangling key chains that make little holes, kids who like to dig, etc. The most recent stove is a 6" batch-box heater of Peter van den Berg's design. Much as I like the standard 8" model, I wanted to make something that would seem more "normal." (I rent my home and want any future resident to be able to stay warm easily. So it was worth the $500 I had to pay a welder to make me a door and frame.) It performed well for the pre-installation test run, but when I installed it, I had to change the sequence of bells and complicate airflow. That may have created back-pressure.

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In addition, I only minimally insulated the firebox. As a result, it doesn't burn as clean as I'd like. It also generates a LOT of condensation, which is going to require some additional tinkering… But my wife loves how easy it is to load and light, and we've been toasty warm through one of the coldest snaps we've ever had here. (We've also been burning far less fuel, but we did add 8" of additional ceiling insulation when we put a new roof on last summer. Insulate, insulate, insulate!)

Important lessons

• Plaster the interior of a masonry flue as smooth as possible to minimize friction/drag on the gas flow.

• Plastering is easier if you smooth each successive section as you go.

• Eliminate corners, for gas flow; adjust the thickness and shape of your adobes and plaster them.

• Cleanouts are important! I've used bricks and/or stone to seal openings that I only opened once a year. To seal them, I used a thin line of mud mortar on the outside edge of the brick. My latest stove has cleanouts made from a pair of pot lids from the Salvation Army store. I found two that fit tight and then cut the center out of the larger one, leaving "teeth" for anchoring them in the mud. I have experienced (and been able to correct) some leakage, so it's important to make sure you get a really tight fit.

• Keep channels sized according to cross-sectional area.

• "Bell" theory: Imagine your stove as plumbing, but instead of flushing water, it's flushing hot gas. Like water, hot gas separates into layers: hot stuff on top, colder below. If you make chambers instead of vents, and connect them at the bottom (so colder gases can still flow through), you'll have what's called a "bell stove." These have advantages. (For more, see the Articles section of www.stovemaster.com.)

Insulative mixes for clean, hot combustion

This is an area worth exploring on the web and/or Donkey's bulletin board, as much work is being done, especially in strengthening local clays by amending them with potassium (made by soaking wood ashes in water). Personally, I've cast Burn Tunnels from pumice and refractory cement (expensive), a clay-sawdust mix fortified with Portland cement (cheaper but also softer), and just plain clay and sawdust or perlite. Any way you do it, however, the material is soft and wears much faster than brick. The sawdust-clay mix (without added Portland) made a fine insulator for the Heat Riser—all the sawdust burnt out, leaving lightweight clay foam. The foam is very fragile but held up until I rebuilt the stove. When I touched it, it collapsed. Again, worth exploring further, I think.

—Kiko Denzer

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Glossary

Our Glossary is idiosyncratic. It defines usage by Ianto and Leslie of some terms you won't find in a dictionary, some are generally known, but we may be using them in particular ways.

** Indicates a term not found in Webster's*

*** Burn Tunnel** – horizontal duct connecting Feed Tube to Heat Riser.

cob – mineral-fiber composite building material made of clay soil, sand, water, and straw, smeared together to cohesive consistency.

*** Combustion Unit** – all parts of a Rocket Stove that enclose fire.

cord – unit of firewood measurement, a stack of 4 feet wide by 4 feet high by 8 feet long.

duct – pipe, any shape, that carries gas or air.

exhaust – all ducts downstream of the Combustion Unit.

*** Exhaust Flue** – stovepipe or duct that leaves the building, or carries exhaust gas out of the stove.

*** Feed Tube** – vertical shaft into which fuel feeds itself by gravity.

flue – any duct that carries hot gases.

*** Heat Riser** – internal insulated chimney carrying burning/burnt gases up from the Burn Tunnel and pulling air through the Feed Tube.

heat storage – heavy masonry mass through which exhaust gases pass, heating it.

hydrocarbon – any chemical comprising only hydrogen and carbon (loosely, also oxygen).

hypocaust – underfloor heating system of ducts carrying hot gases.

kindling – thin, easily ignited wood used to get a fire going quickly.

*** Lorena Stove** – cookstove system using a sand-clay block that is excavated to accommodate fire and cook-pots.

Manifold – the part of the exit pipe where gases falling from the Heat Riser enter that pipe.

pyrolysis – chemical decomposition of fuel by heat in the absence of oxygen.

refractory – a substance that resists high temperatures.

Rumford fireplace – high-efficiency open fireplace built to a fixed geometry.

specific heat – the amount of heat a material will store, proportional to water, per unit weight.

*** squatments** – neighborhoods that evolve by squatter takeovers.

stack – vertical duct carrying gases.

*** Thermal Battery** – heavy construction designed to store heat for long periods.

thermal mass – comparative term describing total ability of a body to store heat.

*** urbanite** – broken up concrete slabs, e.g. from driveways, sidewalks, etc., used in construction.

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Resources on Pyromania

For 20 years **Cob Cottage Company** has run the North American School of Natural Building in Coquille, Oregon, the first permanent teaching center for Natural Builders in the United States.

Our inspiration comes from direct observation of Nature and from the wisdom of traditional cultures. We are committed to deconsumerizing, to reducing the flow of cash, resources, and waste, and to helping others do the same. We work with a wide range of natural materials, mostly unprocessed.

We conduct hands-on research on Natural Building methods and materials, testing our own buildings by living in them. Through **practical trainings** in natural construction, we help empower ordinary people to build their own houses at moderate cost.

At our 30-acre forest site in southwest Oregon we have almost a dozen Rocket Mass Heaters, several Pocket Rockets, plus other wood-burning stoves. It's well worth a visit. Our **"Pyromania!" workshops** are for those in love with fire. Learn how fire burns, what makes combustion efficient, and how to build the ultimate in snug energy-saving campfires, stoves, and fireplaces for cooking and comfort—all handmade at almost no cost. During the weekend workshop we burn and evaluate several models, as well as build one or two. Cob Cottage Company's Pyromania! workshops often occur spontaneously and fill up quickly. Keep an eye on the Schedule of Workshops on our website.

Take Pyromania! workshops, find updates to this publication, access the brain trust of Ianto Evans on Rocket Stoves and other things related to Natural Building, and find the very best Natural Building books available at our mail-order bookstore. Contact info:

Cob Cottage Company
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Coquille, OR 97423
Phone: (541) 396-1825
Website: www.cobcottage.com

Visit us online: **www.rocketstoves.com**

Here you will find this book for sale in both "bit" and "atom" versions, as well as other Natural Building titles. The website also has updates to this book, photographs, further case studies, submissions of innovations to stoves from readers like you, and an opportunity to find—and list—workshops in your own region.

The very popular discussion forum for stovers is moderated by Kirk "Donkey" Mobert and is a regular hang-out for almost all who have contributed to this book. Expert stovers from all over the world contribute. It is lively, welcoming, smart, and up-to-date. Find questions to your answers and answers to your questions here: **www.donkey32.proboards.com.**

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Good Books on Natural Building & Wood Burning

★Evans, Ianto, Linda Smiley, and Michael G. Smith. *The Hand-Sculpted House: A Practical and Philosophical Guide to Building a Cob Cottage.* Chelsea Green Publishing. 2002.

★Evans, Ianto. *Lorena Owner-Built Stoves.* Volunteers in Asia. 1980 (reprint).

★Denzer, Kiko. *Build Your Own Earth Oven: A Low-Cost, Wood-Fired Mud Oven, Simple Sourdough Bread, Perfect Loaves.* HandPrint Press. 2000–2007.

★Denzer, Kiko. *Dig Your Hands in the Dirt! A Manual for Making Art out of Earth.* HandPrint Press. 2005.

★Edleson, Max and Eva. *Build Your Own Barrel Oven: A Guide for Making a Versatile, Efficient, and Easy to Use Wood-Fired Oven.* HandPrint Press. 2012.

Wisner, Erica. *The Art of Fire.* 2013.

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Soderstrom, Neil. *Heating Your Home with Wood.* Harper and Row. 1978.

Barden, Albert and Heikki Hyytiainen. *Finnish Fireplaces: Heart of the Home.* Finnish Building Center. 1988.

Shelton, Jay. *The Woodburner's Encyclopedia.* Vermont Crossroads Press. 1976, etc.

★Orton, Vrest. *The Forgotten Art of Building a Good Fireplace: The Story of Sir Benjamin Thompson, Count Rumford, an American Genius.* Yankee, Inc. 1969.

Lyle, David. *The Book of Masonry Stoves.* Chelsea Green Publishing. 2000.

Burnet, Pascal. *Rocket Stoves – Feux de bois et poêles de masse.* A translation into French of *Rocket Mass Heaters*, Second Edition. 2009.

★Crews, Carole. *Clay Culture: Plasters, Paints and Preservation.* Gourmet Adobe Press. 2009.

★Kennedy, Joseph, Michael G. Smith, and Catherine Wanek, Editors. *The Art of Natural Building.* New Society Publishers. 2002.

Ludwig, Art. *Builder's Greywater Guide. Installation of Greywater Systems in New Construction and Remodeling.* Oasis Design. 1995–2004.

★Ludwig, Art. *Principles of Ecological Design.* Oasis Design. 2003.

★Ludwig, Art. *Create an Oasis with Greywater. Your Complete Guide to Choosing, Building and Using Greywater Systems.* Oasis Design. 1994–2006.

★Ludwig, Art. *Water Storage: Tanks, Cisterns, Aquifers, and Ponds.* Oasis Design. 2005.

★Kahn, Lloyd. *Builders of the Pacific Coast.* Shelter Publications. 2008.

★Kahn, Lloyd. *Tiny Homes: Simple Shelter.* Shelter Publications. 2012.

★Kahn, Lloyd. *Home Work: Handbuilt Shelter.* Shelter Publications. 2004.

★Kahn, Lloyd and Bob Easton. *Shelter.* Second Edition. Shelter Publications. 2000.

Bies, Vital and Marie Milesi. *Poêles à accumulation.* Terre Vivante. 2008.

★*Available by mail from Cob Cottage, 2014*

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A Few Good Websites

Feed "Rocket Mass Heaters" into a web search engine and hundreds of results pop up: Images, instructional videos, outrageous claims of 100% clean combustion, delightful inventions, and frightful disasters—all launched by folks inspired by this stove, and this book. Well-meaning, but sometimes off the mark. I have seen only some of the materials out there; it's impossible to control the flow, so bring it on, I say. Here are a few sites I can highly recommend. LESLIE

www.cobcottage.com
Workshops on Natural Building, and "Pyromania!" weekends. Take a tour, join a work party.

www.rocketstoves.com
The book's official site. Lists resources and workshops, houses the forum. Additional photos, innovations, and updates.

www.donkey32.proboards.com
"Experimenters Corner...Answers Questioned." All that and more about Rocket Mass Heaters. Moderated by Kirk Mobert and Peter van den Berg.

www.handprintpress.com
This site originated by Kiko Denzer has great articles on earthen art, wood burning, and learning by doing. See especially the archive on home heat: www.handprintpress.com/home-heat.

www.firespeaking.com
Max and Eva Edleson's site. Masonry heaters, wood-fired ovens, Natural Building. Great masonry stove info. See especially their articles on bell design: www.handprintpress.com/rmh-and-bell-research.

www.mha-net.org
All things masonry stove. Great community of people. Excellent articles about masonry heating.

www.ernieanderica.info
Erica and Ernie Wisner's site. Hands-on teachers of creative, ecological, and practical skills. Purchase plans for well-tested RMHs, purchase books.

www.potentialenergy.org
Increase access to safe and clean energy technology. Developers of the Darfur-Berkeley stove.

www.permies.com/forums/f-55/stoves
A forum moderated by Ernie and EricaWisner, covering mostly Rocket Stoves for heating and cooking.

www.rechoroket.com
Rocket Stoves in Haiti: See especially the article "Ten Principles." www.rechoroket.com/Ten_Principles.

www.repp.org/discussiongroups/resources/stoves
Renewable Energy Policy Project (REPP). Discussion group and biomass stoves page.

www.woodstove.com
Woodstock Soapstone Company sells soapstone wood- and gas-burning stoves. Their website offers rich informative and practical articles on wood-burning stoves, such as "Wood Burning Basics."

www.fornyetenergi.dk
Flemming Abrahamsson's concern in Denmark. A wealth of information on Natural Building, masonry stoves, and Rocket Mass Heaters. Site is also in English.

www.oasisdesign.net
Art Ludwig's site. Everything you ever wanted to know about water design, and then some. Books, videos, teaching; resources galore.

www.canyonartz.com
The website of Lasse Holmes. Find resources for the Alaska-style Rocket Mass Heater. Workshops, kits, plans, etc.

Purchased by Johnathan Yelenick, johnathan.yelenick@gmail.com #11023292

ABOUT THE AUTHORS

Ianto Evans is an applied ecologist, landscape architect, inventor, writer, and teacher, with building experience on six continents. He teaches ecological building and has consulted to USAID, World Bank, US Peace Corps, and several foreign governments on improved cookstoves, fuel supplies, and kitchen technology. Ianto developed the Lorena Stove in Guatemala in the 1970s—the first really successful widespread do-it-yourself cookstove. He is a founder of Aprovecho Institute, Cob Cottage Company, The Natural Building Colloquium, and the North American School of Natural Building, where he teaches weekend Rocket Mass Heater workshops.

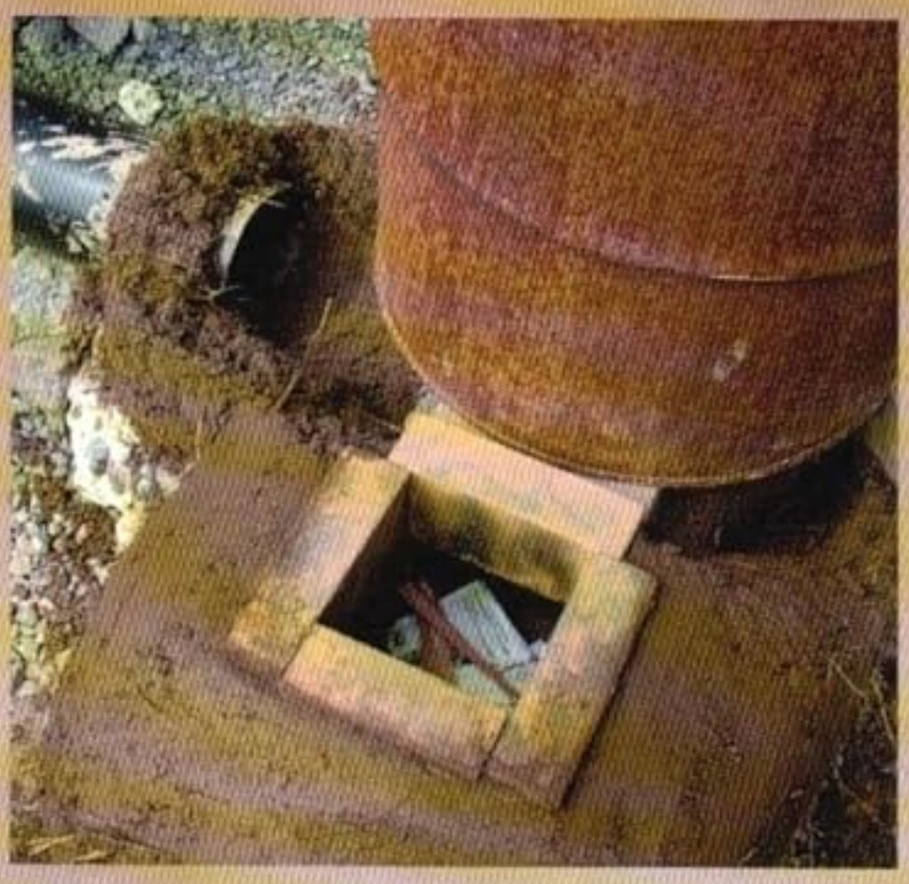
Photo: Matt Anderson

Leslie Jackson produced a DIY 'zine in 1991 called "Pros and Cons: A 'lit 'zine for Penned Pens." In the true spirit of punk 'zines, she stole company time on her employer Melvin Belli's computer and printed in his law firm's copy room after hours. With this 'zine in hand—and thanks in no small part to Jay Baldwin—she got to cut her teeth at *Whole Earth Review* magazine. Leslie's writing has appeared in *Home Power* magazine, *Home Energy* magazine (where she was also Assistant Editor), *Permaculture Activist*, and *No Regrets Remodeling*. Leslie is in a Body Music troupe called MoToR, plays ethnic traditional music, and dances at the crossroads of high- and low-tech in Oakland, California.

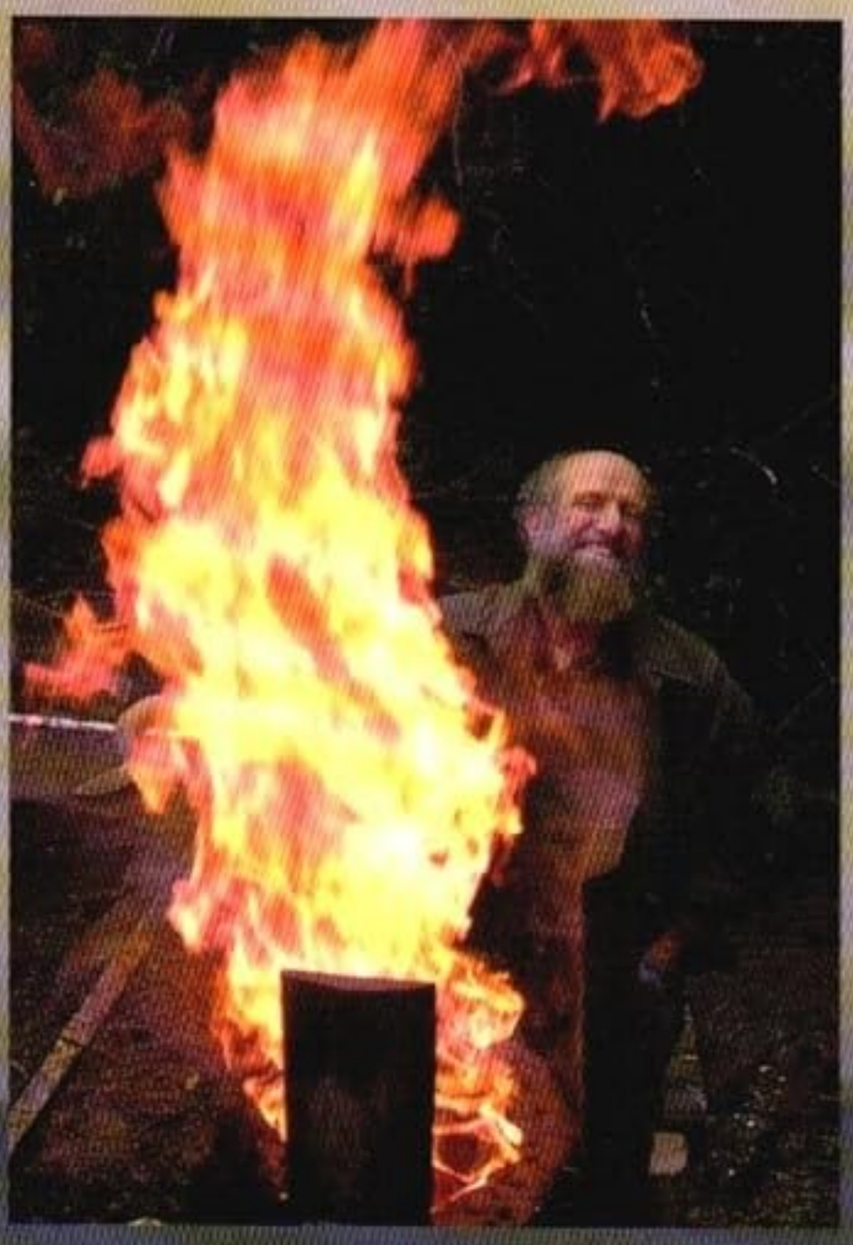
Photo: David Eisenberg

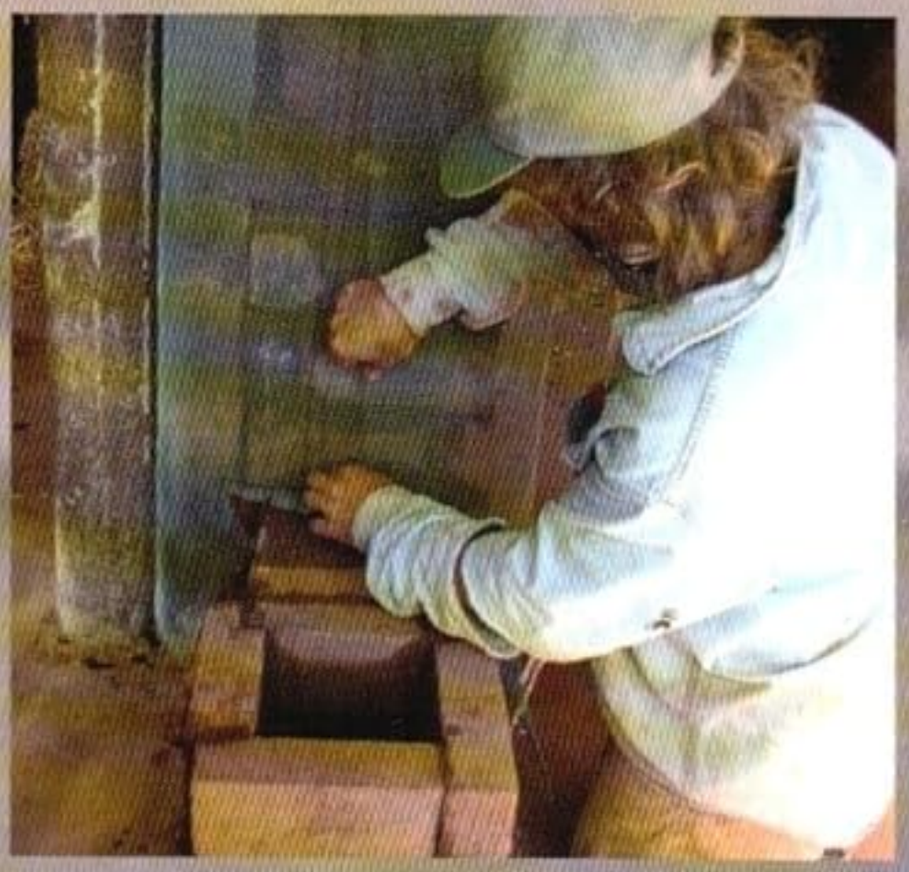
Purchased by Johnathan Yelenick, johnathan.yelenick@gmail.com #11023292

I frequently talk with people interested in adding a rocket mass heater to their home who are concerned about the floor space it will "take" away from their house. Once you enter into a relationship with a mass bench you realize that in the winter especially (and spring and fall in Alaska!), that it is the preferred place to be and therefore it is actually "giving" floor space. I have noticed a tendency of female visitors in particular who, after getting introduced to the bench, essentially melt into it for hours, at times making it difficult to remove them. Perhaps a human scale spatula might need to be invented! --Lasse Holmes



This book is about bringing comfort home to the bench or bed you sit or lie down on. Ecological Designer Ianto Evans, a visionary in Natural Building and an expert in improved wood burning stoves, who has been heating his home with a Rocket Mass Heater for over 25 years will inspire you to make one of your own. With clear and clever drawings and anecdotes, this book contains: philosophy of wood burning and home heating, experiments you can do to learn efficient wood burning, and instructions for building a Rocket Mass Heater yourself. A full color Case Study section introduces you to several stovers working with a range of adaptations from low- to high-tech.





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